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PROCEEDINGS

of the

second midwest

PRAIRIE CONFERENCE

held at

UW - Madison Wisconsin UW - Parkside

September 18, 19, 20, 1970

edited by James H Zimmerman

Naturalist, University of Wisconsin Arboretum

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PREFACE

Coordinating this conference was a great pleasure. Primary credit is due to Peter Schramm of Knox College, who conceived and carried off the first prairie conference in 1968. The enthusiasm discovered and generated there made a second conference a certainty. With a quarter century of prairie restoration, the University of Wisconsin Arboretum at Madison was a logical place. The then Arboretum director, David Archbald assembled a committee which, despite the press of other work, kept the preparations on schedule.

Preliminary arrangements were executed by Virginia Kline, Robert Ellarson and David Archbald. Rosemary Fleming took on the considerable task of reservations for the meetings, trips and meals, continuing throughout the meetings. Grant Cottam kept the committee on schedule and was master of ceremonies at the banquet. Eugene Gasiorkiewicz found speakers and executed all arrangements for the part of the program held at UW-Parkside, with the help of a local committee at Racine, as well as Parkside Chancellor Irvin G. Wyllie. Mrs. Kline handled Madison trips and guides.

This conference would not have been possible without the nearly full-time attention during June-August of Oliver Steinberg, who acted as anchor man and took care of all mailings, correspondence, many details of arrangements, and the design and printing of the program brochure. Assisting, mainly with typing, were David Schwehr, Caroline Clark and Dorothy Camper. Clifford Germain took care of exhibits, assisted by several exhibitors. The Friends of the UW Arboretum and the UW Arboretum Committee acted as hosts. Present Director Roger Anderson did much to keep the meetings running smoothly.

These proceedings - as well as the conference - are largely due to the hard work and fine cooperation of those who prepared the papers and/or moderated the sessions. Reviewing and editing was shared between Drs. Roger Anderson, Edward Beals, Grant Cottam, and myself. Typing by Mary Antonioni, and the contribution of sketches by my wife, Elizabeth, made possible the printing of this volume, which includes six pieces which could not for various reasons be presented at the meeting: Iltis, Wuenscher, Burton, Leopold, Threlfall, Zimmerman.

The conference paid for itself, given the donation of time, energy and some financial loans by many persons. It would have been possible to publish a year ago had not several critical conservation and administrative problems intervened.

It should be noted that neither a grant nor a formal organization has been necessary for the success and continuity of the prairie conference series, which thus serves a need whenever, but only as long as, the need exists.

The first conference drew attention to prairies and assembled diverse persons interested in prairies. The second began to reveal special concerns, which developed further after the conference: The need for more rapid and effective preservation and restoration efforts; the need for large scale propagation of a greater diversity of prairie plant species, especially forbs; and the need to focus on locally-adapted populations as sources for establishment, to assure best performance and permanence as well as protecting native strains from contamination or competition.

The second of these concerns, brought forward by Jim Wilson, led immediately to a special meeting. As a result, some progress has now been made through the cooperation of Dr. Anderson at the UW Arboretum, the Wisconsin Department of Natural Resources, and the Soil Conservation Service plant materials centers, in developing propagation facilities and testing stock from local sources in pilot trials in 1972. Much more work is needed in each state, and a coordinator is needed to rally the help of those who indicated interest in forb propagation. The list of these persons is available from the UW Arboretum.

James H. Zimmerman, Coordinator.
Naturalist, U.W. Arboretum,
1207 Seminole Hwy., Madison, Wis. 53711
Lecturer, Institute for Environmental
Studies and U.W. Extension.

June, 1972

NORTHWARD EXTENSIONS OF PRAIRIE ON SANDY SOILS OF CENTRAL WISCONSIN

By

P.B. Whitford

Department of Biology, University of Wisconsin--Milwaukee

ABSTRACT

Native prairie vegetation was common in presettlement time in the southern and southwestern parts of Wisconsin, but it is interesting to note that in central Wisconsin a few areas up to several square miles and numerous smaller sites have been recorded up to 50 or even 75 miles north of the major mesic prairie areas. These are found in Waushara, Portage and Waupaca counties, generally on outwash sands. Species presence lists and edaphic data were obtained for 20 relict stands in this area.

In general these areas have a somewhat different species composition from that of the silt-loam and clay-loam prairies farther south, but have more resemblance to the sand prairies of the lower Wisconsin River terraces and some affinity with oak barrens and jack pine barrens. Some species common in southern counties are not present or much rarer, e.g. Silphium laciniatum, while others are much more common here than southward. These sites all have the general aspect of prairies, however. The controlling factor maintaining these areas against forest invasion here seems to be a drouthy surface soil, perhaps abetted by poor internal and external drainage in wet seasons as some have clay layers below and many are flat and near the spring-time water table Coarse, drouthy, low-nutrient soils and frost pockets can explain the attenuation of southern species and the presence of some northern ones.

Introduction

Presettlement prairie vegetation existed on sizable areas far into the otherwise forested region of central Wisconsin, especially on sandy soils of glacial outwash terraces. Since prairies represent a somewhat isolated extension of prairies, 50-75 miles north of the major mesic prairie areas of south-central Wisconsin, and also a rather distinct edaphic situation, it seemed desirable to study them further. The sites are in Portage and Waushara Counties and the westernmost part of Waupaca County, near the geographic center of the state, and are found on intermorainal sandy outwash terraces, often overlying gravelly subsoils. The area is east of the northern half of the bed of Glacial Lake Wisconsin and east of the present Wisconsin River (Figure I).[1] The uplands surrounding these prairies are rolling to strongly rolling moraines originally covered by oak or oak-pine mixtures ranging from savanna to fairly dense forest.

Soils of the study sites are chiefly sands or sandy loams (Figure I) of the Coloma, Plainfield, and Waukesha series (Hole and Lee, 1955). Average summer temperatures are about 68° F, average snowfall is about 45", and annual precipitation about 31 inches. However the area is more subject to late spring and early fall frosts than surrounding areas.

The areas concerned were first delineated from soils and topographic maps. Then an aerial reconnaissance was made in late May to search for likely remnants of native prairie. It was discovered that a combination of colors and textures indicating prairie species such as Phlox pilosa, Zizia aurea[1], tall bunch grasses, etc., was readily recognized at this season from altitudes of about 500 feet. Also the general areas and shapes of the original prairies were readily discernable by their flatness and the darker-colored soils where plowed. Much of the original area is currently used for irrigated truck crops such as potatoes and snapbeans.

After the aerial reconnaissance the marked sites were visited during June and July and a few other sites were located by cruising likely roads at low speed. A total of 20 sites in this area were thus selected and complete presence lists were made at each site. Most sites were also rechecked in September or early October for positive identification of late-flowering species. A record form was also made out for each site, giving details of location, condition, topography and soil profile; soil samples were taken with a standard core sampler from both surface and subsoil levels.

---

[1] Nomenclature follows Gleason, H.A. and A. Cronquist. 1963. Manual of Vascular Plants eastern United States and Adjacent Canada.

Fig. I is in Map Section

Presence lists were used for calculations of % presence and continuum values, and for comparisons with other Wisconsin prairie areas (Curtis and Greene, 1949). Soil samples were analyzed at UWM for colloidal fraction by the Cenco-Wilde hygrometer method, for pH using a Beckmann pH meter, and for weight per volume. These analyses were done by the State Soils Lab at Madison for Organic Matter, P,K,Ca, and Mg.

Results

a. Composition and continuum:

The species lists for the 20 sites included a total of 142 native species, of which 46 occurred on at least half of the sites, i.e., at least 50% presence; these are listed in Table 1 in descending presence values. These 46 species, which may be considered "common" or "typical" of these prairies, are mostly species of rather wide distribution in Wisconsin and only two occur in fewer than nine of the 34 communities outlined by Curtis (1959) in his Vegetation of Wisconsin. Although 29 (nearly 2/3) of these 46 common species are listed as "modal" species (i.e., higher presence % than in other communities) in one of the five segments of his "prairie continuum", it is also true that in general they are species not restricted to true prairies. The remaining 17 species have modal values in other more or less open communities such as oak barrens (5 spp.), cedar glade (5 spp.), southern xeric forest (3 spp.), etc. (Curtis, 1959). Of the 29 common species which are modal in the prairies, 11 are mesic prairie species, seven represent dry-mesic and six dry, while four are modal in wet-mesic and only one in the wet prairies. Thus the total picture is of a generally mesic prairie type but somewhat on the dry side, yet with a considerable range of moisture adaptation. Of the 50 species Curtis (1955) designated as "indicator species" for the five segments of the prairie continuum (10 in each segment), only five of the wet prairie species occurred in any of these 20 sites, while eight each of wet-mesic and dry-mesic, and six each of mesic and dry ranges were found here. Continuum index values (Curtis, 1955) were calculated for each stand and ranged from 213 to 425 with a mean value of 329, which again is a bit on the dry side of mesic (theoretical range if from 100 if only "wet" indicators were present to 500 if only "dry" indicators were present).

It should also be noted that the Almond-Oasis prairie sites in Waushara and Southern Portage Counties are somewhat drier, as indicated by continuum values, than are those of the Arnott-Amherst area farther north in Portage County, averaging 362 in the former vs. 289 in the latter. In clay loam prairies in southeastern Wisconsin (Whitford, 1958) the continuum index averaged 274, i.e., wetter than mesic.

The total list of 142 native species compares favorably with 173 species on 60 sites in Racine and Kenosha Counties (Whitford, 1958) and 109 species in Rock County (Green, 1950). In the Racine-Kenosha study 48 species had over 50% presence, whereas 46 species had at least 50% presence in these Portage-Waushara stands.

b. Species differences compared with other Wisconsin areas:

Nineteen of the species found in these outwash prairies in central Wisconsin were not found in the clay soil prairies of southeastern Wisconsin, while 23 other species were much higher in presence here (Table 2). Conversely, 25 species known to occur commonly on prairies farther south in Wisconsin are absent from these northward extensions, and another 12 species are of much lower presence here than southward (Table 3). The list of species which are notably missing in this area includes a number of the most common and typical species of Wisconsin prairies. Four of the 20 leading species in southeastern Wisconsin (as ranked by C x ave. F; Whitford, 1958) were among those missing here (Ratibida and all three spp. of Silphium), and similarly eight of the 55 prevalent species listed by Curtis (1959) for mesic prairies are absent here, as are seven of his 43 prevalent species for dry-mesic prairies.

Among the species present in this area but not in southeastern Wisconsin clay-soil prairies (Table 2) only seven have modal values in prairie types while six are modal in sand barrens, three in bracken grassland and two in oak barrens (Curtis, 1959), indicating that these prairie extensions have some habitat factors which approach those of these more northern and western non-prairie communities.

Table 1: Occurrence of Major Species in Prairies of Portage and Waushara Counties, Wisconsin*

SPECIES	NUMBER OF STANDS	PERCENT PRESENCE
Andropogon gerardi	20	100
Euphorbia corollata	19	95
Asclepias syriaca	18	90
Aster azureus	18	90
Physalis virginiana	18	90
Achillea millefolium	17	85
Rudbeckia hirta	17	85
Solidago nemoralis	17	85
Amorpha canescens	16	80
Anemone cylindrica	16	80
Antennaria sp.	16	80
Aster ericoides	16	80
Corylus americana	16	80
Erigeron strigosus	16	80
Helianthus strumosus	16	80
Liatris aspera	16	80
Andropogon scoparius	15	75
Agropyron trachycaulon	15	75
Lespedeza capitata	15	75
Rosa sp.	15	75
Salix humilis	15	75
Stipa spartea	15	75
Tradescantia ohi ensis	15	75
Asclepias tuberosa	14	70
Coreopsis palmata	14	70
Fragaria virginiana	14	70
Helianthemum canadense	14	70
Panicum leibergii	14	70
Solidago missouriensis	14	70
Solidago rigida	14	70
Apocynum androsaemifolium	13	65
Phlox pilosa	13	65
Potentilla arguta	13	65
Solidago speciosa	13	65
Lactuca canadensis	12	60
Houstonia longifolia	12	60
Monarda fistulosa	12	60
Solidago juncea	12	60
Sorghastrum nutans	12	60
Lobelia spicata	11	55
Panicum oligosanthes**	11	55
Smilacina stellata	11	55
Aster laevis	10	50
Geum triflorum	10	50
Helianthus occidentalis	10	50
Sisyrinchium campestre	10	50

*46 spp. of 50% presence on 20 stands listed, all on outwash sands.

**P. oligosanthes is here used as a collective term for a complex group, which may include several species, varieties and hybrids, impossible to distinguish in the field. (cf. Freckmann, 1967).

Table 2: Species not present in southeastern Wisconsin or much lower in presence there.

A. Present in Portage and Waushara counties, absent in S.E.

Agropyron trachycaulum	75% presence	*
Asclepias ovalifolia	35	*
Artemisia caudata	40	*
Aster sericeus	25	*
Gnaphalium obtusifolium	45	*
Hedeoma hispida	35	*
Heiraceum canadense	10	
H. longipilum	40	
Helianthemum canadense	70	
Helianthus occidentalis	50	
Houstonia longifolia	60	*
Koehleria cristata	40	*
Linum sulcatum	25	*
Lithospermum croceum	40	*
Lupinus perennis	40	*
Monarda punctata	10	*
Pteridium latiusculum	45	*
Solidago juncea	60	
Solidago speciosa	65	

*Present locally in S.E. Wisconsin but not in clay-soil prairies of Racine and Kenosha counties.

B. Species of much higher presence in portage-Waushara area.

	% Presence in N. Ext.	% Presence in S.E.**
Amorpha canescens	80	32
Apocynum androsaemifolium	65	25
Asclepias tuberosa	70	5
Aster azureus	90	17
Astragalus canadensis	20	2
Coreopsis palmata	70	33
Corylus american a	80	40
Geum triflorum	50	5
Lespedeza capitata	75	37
Liatris aspera	80	30
Lobelia spicata	55	12
Panicum leibergii	70	32
Panicum oligosanthes+	70	5
Physalis virginiana	90	48
Potentilla arguta	65	37
Rudbeckia hirta	85	40
Salix humilis	75	23
Sisyrinchium campestre	50	17
Smilacina stellata	55	30
Sorgastrum nutans	60	30
Stipa spartea	75	40
Tradescantia ohiensis	75	17

**Whitford, 1958

+See footnote, Table 1.

c. Soils:

The results of soil analyses for 10 characteristics were averaged for these 20 stands. These averages are compared in Table 4 with averages from 82 stands surveyed for a paper now in preparation on prairie remnants of east central Wisconsin (which include the 20 sites of this study) and with averages from over 60 stands in Racine and Kenosha Counties in southeastern Wisconsin (Whitford, 1958). The trends are obvious in the table, with these northern sites averaging > 4x the southeastern area in P, but only about 1/2 as much K, 1/6 as much Ca, 1/3 as much Mg, and with distinctly lower pH, colloidal content and water retaining capacity as compared to the southeastern sites. No gley horizon was found here compared to the southeastern stands 1/3 of which had a gley horizon within 30" or less of the surface. In practically all factors the averages for east central Wisconsin prairies are intermediate, reflecting a range from sandy loams to silt loams to clay from varied parent materials, compared to the sandy loams on outwash in northern sites and the clay loams on intermorainal till in the southeastern area. At least 3/4 of the northern outwash sites have layers of gravel within 3' of the surface, in fact 1/2 had gravel within 2', preventing the development of a normal "B" horizon and allowing excessive internal drainage. Certainly these edaphic factors play a role in the differentiation of these northern prairie extensions.

Discussion

The differences in species composition described above are undoubtedly related to climatic, microclimatic and edaphic differences, although unfortunately it is very difficult to separate specific factors as applied to individual species.

The Portage-Waushara County area is subject to frosts in late spring and early fall, even more so than in Marathon County next northward, and therefore constitutes a major "frost pocket" area which is accentuated on these prairies by the lack of tree canopy and by their low topographic situation. Low open sites in this area are subject to frost even in mid-summer in some years, and the average frost-free season is at least six weeks shorther than that in the Racine-Kenosha area and about a month shorter than at Appleton, directly eastward (Wisconsin Crop Reporting Service, 1961). Since average annual rainfall, number of rainy days and July evaporation are essentially the same as in southeastern Wisconsin (ibid), it appears that climatic moisture is not a differentiating factor. July isotherms and average summer temperature maps show a difference of only 1-2° F, so it would appear to be the frost factor and short growing season which limits the more southern prairie species not found here, such as Silphium and Ratibida. Both Silphium terebinthinaceum and Ratibida occur equally far north in the Fox Fiver Valley to the east, in an area not so subject to frost and with three-four week longer growing season.

The presence of species such as bracken fern, Pteridium latiusculum (45%), Heiracium canadense (10%), and Agropyron trachycaulum (75%), which are prevalent and modal species of the bracken-grasslands in the northern counties of Wisconsin (Curtis, 1959) and therefore obviously frost-tolerant, is further evidence for the assumption that frost is a major factor here. These species apparently do not compete successfully in most mesic prairies further south and are absent in the Racine-Kenosha prairies. Frost occurring during summer months on these sites may also inhibit woody species and favor herb dominance on these sites (Parker, 1963; Whitford and Whitford, 1969).

Edaphic factors are probably responsible for the absence of some typical prairie species. These factors include those involving mineral nutrition and those related to soil drouth, with pH possibly as a direct factor but more likely acting indirectly through its relation to nutrient availability. Organic matter, K, Ca and Mg average 1/6 to barely over 1/2 the corresponding levels in southeastern Wisconsin, though to determine which may be limiting for a given species of course would require more extensive experimental data. The very low water-retaining capacity and low colloid percent in both surface and subsoil would of course indicate a drouthy condition aggravated by gravelly subsoils in 3/4 of these sites, which thus might be limiting for some of the wet to mesic prairie species (Burgess, 1961; Partch, 1962). In fact, though these sites are mostly in low, nearly level, topographic pos-

itions, only one of the 46 species of ≥ 50% presence is considered by Curtis (1959) to be a wet-prairie species, while six are modal in dry prairies, and 11 are modal in oak barrens, cedar glade, or sand barrens, all of which are on xeric sites.

Thus, even though the continuum index values indicate average conditions only slightly drier than the mesic midpoint, more than 1/3 of the most common species (≥50%P) are species of xeric habitats, outnumbering those of wet habitats by 17:1. Also, of the 25 species of more southern prairie sites which are absent here, more than half (15 spp.) are species of moister sites, having modal values in fen, wet prairie or wet-mesic prairie, whereas only seven are mesic prairie species and two are dry prairie species. Thus it appears that the drouthy edaphic situation may be a major factor limiting many species of higher moisture requirements, while species characteristic of mesic to dry prairies may be limited by frost and short growing season or by poor chemical nutrition. There is also the probability of interaction of these factors, e.g., a growth rate limited by minerals and/or moisture might make a given species more vulnerable to frost or less able to compete in a short growing season.

In general, then, these 20 northern sites in central Wisconsin respresent an extension of the mesic to dry-mesic prairie types but are distinguished by the prevalence of the hardier prairie species and those of broad ecological range, with an infusion of species representing vegetation types which are geographically, edaphically and/or ecologically similar, such as oak barrens, cedar glade, sand barrens and bracken grassland. These remnants do not, therefore, appear to represent a distinct prairie type and no species of high fidelity as possible "indicator" species for this type were noted. Since these sites lie within and just south of the tension zone (Curtis, 1959), it is to be expected that some species of southern affinity would be missing and species of northern affinity would appear.

The low-nutrient, xeric, and frost-prone conditions on these sites may also play a role in inhibiting tree invasion and therefore in maintaining prairie vegetation this far into a forest region (Whitford and Whitford, 1969).

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Table 3: Species Common Farther South Which are Absent or of Much Lower Presence in Portage and Waushara Counties.

A. Species absent in Portage and Waushara Counties:

	% Presence in S.E.
Allium canadense	83
A. cernuum	7
Asclepias viridiflora	2
Aster novae-angliae	73
Calamagrostis canadensis	10
Desmodium illinoiense	2
Dodecatheon meadia	27
Eryngium yuccifolium	27
Gentiana andrewsii	10
Oxypolis rigidior	27
Pentstemon digitalis	5
Petalostemum candidum	5
P. purpureum	35
Prenanthes racemosa	8
Pycnanthemum virginianum	52
Ratibida pinnata	93
Silphium intergrifolium	62
S. laciniatum	47
S. terebinthinaceum	83
Solidago riddellii	25
Spartina pectinata	65
Valerianaa ciliata	7
Vicia americana	77
Viola cucullata	72
Zizia aptera	28

B. Species having much lower presence in Portage-Waushara prairies than in Racine-Kenosha prairies:

	% Presence in N.C.	% Presence in S.E.
Apocynum cannabinum	10	33
Asclepias verticillata	5	45
Baptisia leucantha	5	23
Cirsium discolor	5	62
Convolvulus sepium	5	35
Lathyrus venosus	15	42
Panicum virgatum	5	43
Physalis heterophylla	20	32
Polygala senega	5	18
Thalictrum dasycarpum	20	42
Veronicastrum virginicum	10	52
Viola pedatifida	10	25

Table 4: Soil Characteristics Compared for Three Wisconsin Prairie Areas.

	N Ext.	E.C.	S.E.
- Org. Matter, Tons/A.	38.0	69.3	--
- P, lb/A	67.4	49.2	15.0
- K, lb/A	168.5	195.5	300.0
- Ca, lb/A	157.5	334.9	939.0
- Mg, lb/A	298.0	1105.0	900.0
- pH	5.7	6.5	7.2
- Colloid %	12.0	21.5	--
- Coll. % (Subsoil)	19.2	39.5	66.7
- W.R.C.	40.0	66.0	73.7
# Stands Gley $\leq$ 30"	0/20	26/80	20/60

All data by Philip B. Whitford: The East Central data include the "Northward Extension" covered in the present paper plus 62 other sites ranging south to Columbia County, east to Washington County and northeast to Oshkosh (manuscript in preparation). The southeastern prairies are on clay loam soils in Racine and Kenosha Counties, excluding the sandy area south of Kenosha known as Chiwaukee Prairie (see Whitford, 1958).

RELICT PRAIRIE FLORA OF SOUTHWESTERN MICHIGAN

By

Edward M. Scharrer

Department of Botany and Plant Pathology
Michigan State University, East Lansing, Michigan[1]

ABSTRACT

The tall-grass prairie communities which were present in southwestern Michigan at the time of settlement have been reduced to scattered fragments. Most fragments, now relict flora, are found along railroad rights-of-way. A descriptive study was made in the summer of 1969 encompassing nine counties and 528 sites most of which were along rights-of-way. Of the 68 prairie plants defined for southwestern Michigan, Andropogon gerardi had the highest presence. A frequency study of 19 sites showed each site with 49% or less prairie species. Fire is the primary factor responsible for the persistence of the remaining prairie flora. Further study of rights-of-way, lakeshores and water courses should reveal additional relict flora.

INTRODUCTION

The literature on Michigan prairie is limited. Prior to the description and location of the original Michigan prairies by Veatch (1928), Kenoyer (1930, 1934, 1940, 1943), and Butler (1947, 1948, 1949), only one prairie study had been made (Gleason, 1917). Even though the most extensive areas of original prairie existed in the southwestern part of the state, only two studies are reported from this area (Brewer, 1965; Pokora, 1968). More work has been done in southeastern Michigan and adjacent Canada by Hayes (1964), Rogers (1966), and Thompson (1970). Gleason's study was also in that part of the state. The most comprehensive study was that of an original one, a sand prairie, in central lower Michigan in Newaygo County (Hauser, 1953).

The first objective of my study was to determine the current status of prairie communities in southwestern Michigan. The second was to provide the location and description of prairie and/or populations of prairie species. Lastly, I briefly examined the composition of certain prairie communities.

METHODS

Sites within or near railroad or other rights-of-way were selected for study since they have been found to possess the least distrubed physical surfaces. Secondly, rights-of-way are, or at least in the past have been, frequently burned, a factor probably of considerable significance for the persistence of prairie grasses and forbs.

During the summer and fall of 1969 (from June 18 to October 4), I systematically examined almost all railroad grade crossings for prairie species in the southwestern Michigan counties of Berrien, Cass, St. Joseph, Branch, northeast Hillsdale, western Jackson, Calhoun, Kalamazoo, and Van Buren. (see Map Section for Michigan locations.)

In order to survey as much area as possible, only presence data were obtained.

Deciding which species to use as prairie species was a problem since the criteria for prairie plants are not recorded for Michigan. Out of the total 158 species I recorded during the survey, 68 were chosen to describe the prairie flora. The criteria were as follows: a) the species is a member of some kind of prairie community, b) it was found primarily as an associate of other prairie species, and c) authors or manuals specified the plant as a prairie species.

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[1]Present address: 6085 Brockway, Union Lake, Michigan

Table 1. Presence of prairie species in 528 sites visited in southwestern Michigan

PRAIRIE SPECIES	SITES	PERCENTAGES
Andropogon gerardi	218	42.6
Asclepias tuberosa	131	25.6
Andropogon scoparius	124	24.2
Euphorbia corollata	97	18.9
Lespedeza capitata	86	16.8
Panicum virgatum	70	13.7
Sorghastrum nutans	57	11.1
Desmodium illinoense	53	10.4
Coreopsis tripteris	31	10.0
Solidago graminifolia	45	8.8
Ratibida pinnata	45	8.8
Ceanothus americanus	43	8.4
Panicum oligosanthes	43	8.3
Veronicastrum virginaianum	42	8.2
Helianthus occidentalis	39	7.6
Rudbeckia hirta	35	6.8
Solidago rigida	35	6.4
Corylus americana	33	6.0
Solidago nemoralis	31	5.9
Sporobolus cryptandrus	30	5.9
Anemone cylindrica	30	5.7
Liatris aspera	29	5.5
Rosa carolina	28	5.5
Elymus canadensis	24	4.7
Silphium terebinthinaceum	21	4.1
Asclepias amplexicaulis	20	3.9
Kuhnia eupatorioides	20	3.9
Salix humilis	20	3.9
Sporobolus asper	19	3.7
Solidago speciosa	18	3.5
Desmodium sessilifolium	17	3.3
Asclepias verticillata	17	3.3
Aster laevis	17	3.3
Desmodium canadense	17	3.3
Hieracium longipilum	16	3.1
Potentialla arguta	15	2.9
Baptisia leucantha	14	2.7
Spartina pectinata	13	2.5
Verbena stricta	11	2.1
Amorpha canescens	11	2.1
Aster azureus	11	2.1
Tephrosia virginiana	11	1.8
Cacalia atriplicifolia	10	1.8
Aster ericoides	10	1.8
Comandra richardsiana	10	1.8
Coreopsis palmata	10	1.8
Liatris cylindracea	10	1.8
Lithospermum canescens	10	1.8
Pycnanthemum virginaianum	10	1.8
Stipa spartea	10	1.0
Silphium integrifolium	9	1.0
Heuchera richardsiana	5	1.0
Ruellia humilis	5	0.6
Viola pedata	5	0.6
Carex bicknellii	3	0.6
Liatris spicata	3	0.6
Lithospermum carolinense	3	0.4
Silphium laciniatum	3	0.4
Asclepias viridiflora	2	0.2
Eryngium yuccifolium	2	0.2
Viola pedatifida	1	0.2
Allium cernuum	1	0.2
Aster sericeus	1	0.2
Echinacea pallida	1	0.2
Helianthus mollis	1	0.2
Silphium perfoliatum	1	0.2
Sisyrinchium albidum	1	0.2
Viola Sagittata	1	0.2

RESULTS AND DISCUSSION

Out of 528 sites visited, 345 (67%) contained at least one prairie species. The highest number found at one site was 28 species. Most of the sites rich in prairie species are between 1/4 and 1 mile long. Large numbers of prairie species at any one site were rare.

Sites rich in prairie species are usually within or near an original prairie. Although the literature describing the location and size of Michigan prairies indicated large prairies of from approximately 60 acres to 13,000 acres, there were no doubt innumerable prairies consisting of fewer than 50 acres also. Sites rich in flora, near or distant from an original prairie, are probably remnants of the smaller relicts.

The presence values of the 68 prairie species are given in Table 1. The high-presence species, namely Andropogon gerardii, A. scoparius, Asclepias tuberosa, Euphorbia corollata, Lespedeza capitata, and Panicum virgatum were found beyond the extensive area of relict prairies. Other species were found only in the area of original prairies, for example: Kuhnia eupatorioides, Potentilla arguta, Coreopsis palmata, Helianthus occidentalis, and Desmodium sessilifolium. The distribution of the presence values illustrates that most of the prairie flora is rare.

The associations of prairie species (sites rich in prairie flora) show several patterns of structure. For example, certain species are restricted to sites with a large number of other prairie species. For Lithospermum canescens, all 10 locations are in sites with 18 or more species. Coreopsis palmata was found with 13 or more species in all 10 locations. Helianthus occidentalis was found with 15 or more species in 29 of the 39 sites. For Potentilla arguta 13 of the 15 locations are sites with 15 or more prairie species. And for Stipa spartea, 8 of the 10 sites are in locations with 13 or more species.

Certain very rare species are also found only in sites rich in prairie species. For example, the two sites of Eryngium yuccifolium contain 28 and 27 species. The single location of Allium cernuum has 28 species. The only site of Aster sericeus includes 13 prairie species.

However, other rare species are found with few other prairie species; for example, Echinacea pallida (one site; six species), Silphium laciniatum (three sites; 11, 6, 4 species), and S. perfoliatum (one site; three species).

St. Joseph County contained large acreages of prairie relicts and at present contains the richest concentration of prairie remnants (Table 2). Of the 12 sites with 21 or more prairie species, 10 occur in St. Joseph County.

Frequency studies of 19 sites showed that on all of them the non-prairie species comprised over 50% of the total. The most common non-prairie plants were Rubus spp. and Poa Compressa.

CONCLUSION

Michigan has a distinct prairie flora, most of which is rare in presence and rare in association. Which of the sites are to be called prairie is yet to be defined. The occurrence of prairies are certainly suggested in southwestern Michigan, with several areas composed predominantly of prairie grasses and/or forbs, but these areas are small or narrow and do contain a high percentage of non-prairie species. Soils, topography, and disturbance need to be studied at the sites suggested here as being remnants.

Table 2. Summary of the Number of Prairie Plants per Site for Each County.

# OF SPECIES	COUNTIES										
	BERRIEN	KALA-MAZOO	ST. JOSEPH	VAN BUREN	JACKSON	CASS	BRANCH	CAL-HOUN	HILLS-DALE	EATON	
0	40	26	9	37	12	21	11	11	10	0	177
1-5	39	49	23	18	32	18	25	18	13	0	235
6-10	5	9	15	6	13	5	5	4	2	1	65
11-15	0	0	10	2	3	2	1	3	3	0	24
16-20	0	0	5	5	2	1	0	3	0	0	16
21-25	0	0	8	0	0	0	0	0	0	0	8
26-30 (28)	0	0	2	1	0	1	0	0	0	0	4
	84	84	72	69	62	48	42	39	28	1	529

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THE PRESERVATION OF PRAIRIE STANDS IN MICHIGAN

By

Paul W. Thompson
Michigan Natural Areas Council and Michigan Nature Conservency
17503 Kirkshire Road, Birmingham, Michigan

Early settlers in Michigan mention and describe a number of prairies in the southern part of the state--apparently scattered and often associated with prairie soils. Butler (1947) describes a number of the well-known prairies of settler days. Because of the fertility of the soil and the ease of cultivation such areas were among the first to be homesteaded and put into agricultural use. Consequently, only remnants of these areas remain today and prairie stands of any size are rare in Michigan.

Because of the scarcity of prairie tracts and the interest in this unique kind of vegetation as ecological communities, in addition to the historical and educational value of prairie, the Michigan Natural Areas Council, during the past several years, has carried out a program to locate, survey, and preserve a number of prairie stands in the state. Four tracts have now been dedicated for preservation: (See Map Section for Michigan locations.)

The Ann Arbor Wet Prairie, located on a flood plain of the Huron River, and adjacent to the Penn Central Railroad, has been occasionally burned. Over 250 species of plants have been catalogued, including more mesic species that occupy the higher ground along the edge of the flood plain and the oak-hickory forest fringe (Thomson 1968). The dedicated tract of approximately five acres is under the ownership of the Ann Arbor Parks and Recreation Department. Periodic burning of the stand is planned to maintain prairie conditions.

The Middle Belt Prairie, lying along an old channel of the Huron River, consists of an open oak wookland (oak opening) and an adjoining flat open area. The tract, under the jurisdiction of the Huron-Clinton Metropolitan Authority, has been dedicated as a managed tract in which periodic mowing will be used in an attempt to maintain prairie species. Over 100 species of plants have been catalogued.

Algonac Prairie, comprising four parcels containing prairie species, has been preserved in the Algonac State Park situated along the St. Clair River a few miles north of the the town of Algonac. This relatively flat area is part of the ancient glacial lake plain similar in terrain to that surrounding Detroit. Low situations are often quite wet in the spring and the soil is frequently of a sandy loam type. Over 300 species of plants grow in the area including the rare milkweed, Asclepias sullivantii . Of the four dedicated tracts, one has been established to preserve a stand of blazing star (Liatris); another, located in a low situation, is dominated by prairie cordgrass (Spartina pectinata) and Indian grass (Sorghastrum nutans). Periodic cutting during the late fall will be used in an attempt to prevent infringement of shrubby species.

Newaygo Dry Prairies--A number of small tracts associated with Sparta loam--have been known in the Newaygo locality since the time of the early settlers and were first described in detail by Hauser (1953). Among the species of interest are the prairie avens (Geum triflorum), cactus (Opuntia compressa), silky aster (Aster sericeus) and hoary pea (Tephrosia virginiana). Several years ago the Manistee National Forest, upon recommendations of the Council, dedicated an 80-acre tract to preserve a portion of these unique prairies. Dr. Ronald Kapp and his students from Alma College have established permanent quadrats here to study the effect of burning, cutting, and various management techniques on the prairie vegetation. Recently the Michigan Nature Association purchased 130 acres to preserve additional prairie land.

Several additional prairie remnants in Michigan are now being surveyed to determine which are best suited for preservation. Several interesting stands have been studied at Fort Custer near Augusta, Michigan. Other tracts include a small stand in the Island Lake Recreation Area, a number of locations in Monroe County, a combination of wet and mesic prairie at the western edge of Kalamazoo, an interesting strip of prairie along the railroad at Bertrand, and a wet prairie

near Dayton which contains the rare prairie phlox (Phlox maculata). Several stands, uncovered by Edward Scharrer in his survey of prairie relics (this symposium) are also under scrutiny.

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THE PRAIRIE-FOREST BORDER IN NORTHERN AND SOUTHERN ILLINOIS

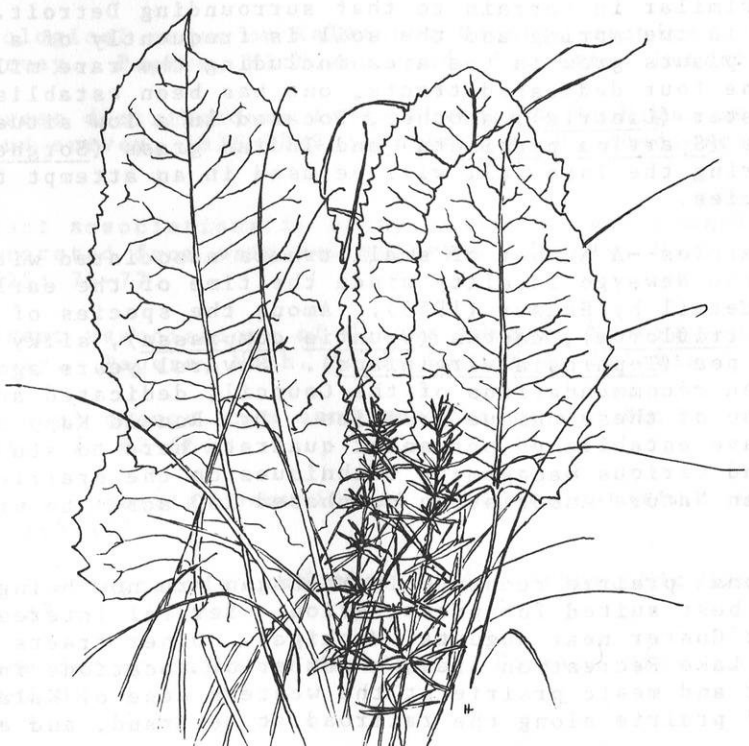
By

Paul D. Kilburn

Principia College, Elsah, Illinois

ABSTRACT

The Grand Prairie of Illinois, which stretches for over 200 miles between St. Louis and Chicago, is bordered by forests of different composition. In northeastern Illinois the border is formed by scattered groves of bur oak (Quercus macrocarpa) as noted by the original survey notes (G.L.O.S.) for Kane County. These groves occur primarily on hills and other areas of irregular topography that would provide both protection from fires and better sites for tree invasion. In the southwest near St. Louis (Jersey County) the survey records show the forest bordering the river in a strip 4-8 miles wide, again in an area of roughened topography. Here the primary tree species in prairie groves and forming the actual border are blackjack (Q. marilandica), post (Q. stellata), and shingle oaks (Q. imbricaria).



PRAIRIE HISTORY, MANAGEMENT AND RESTORATION IN SOUTHERN ILLINOIS

BY

Roger C. Anderson

Managing Director, Arboretum
University of Wisconsin, Madison

ABSTRACT

Prairies were the natural vegetation that covered more than two-thirds of Illinois before white settlement. However, the extreme southern portion of the state was largely forested. A prairie map based on the original land survey records revealed that no extensive prairie occurred beyond the southern limits of Illinoisian glaciation.

Southern Illinois University has leased several areas along railroad rights-of-way that support prairie vegetation for both teaching and research purposes. The outdoor laboratory at S.I.U. has been involved in the construction of an artifical prairie. To date the efforts at prairie restoration have been limited.

Some research has been done to determine the composition of the natural prairie vegetation and its response to fire.

The region designated as Southern Illinois includes that portion of Illinois south of an arbitrary east-west line located about 30 miles south of St. Louis (38° 15' N Latitude). It includes the 17 southern counties and encompasses an area of 6,526 square miles.

Southern Illinois University, at Carbondale, with an enrollment of 24,000 students, is the largest educational institution in the area. This paper discusses some of the work being done at Southern Illinois University (S.I.U.) in prairie restoration and preservation.

Both glaciated and unglaciated landscapes are included within Southern Illinois, However, only the Illinoisian ice sheet extensively covered the area. The southern 2/5 of the region was unglaciated. Before White settlement much of Southern Illinois was forested. The uplands supported oak-hickory forest while beech, maple, and tulip trees were common in ravines. The extreme southern portion of the state had deep swamps of cypress and water tupelo. Prairies, while not extensive, were part of the original vegetation. Many of these prairies, such as Burnt Prairie, Belle Prairie, Elk Prairie and others, were named by the early settlers (Voigt and Mohlenbrock, 1964).

The earliest maps of prairies in Illinois (Gerhard, 1875) showed little prairie in the southern portion of the state. Vestal's (1931) map of the vegetation of Illinois vastly improved our understanding of the southern prairie-forest border in Illinois. His map showed more prairie in the southern portion of the state. A map[1] of prairies in Illinois based on the Government Land Office surveys, Figure I, provides more detail of the location of prairies (Anderson, 1970). More prairies are shown in Southern Illinois. The most extensive grassland, the Grand Prairie, occurred in Northeastern Illinois in that area covered by the Wisconsin ice sheet. The more eroded or dissected till of the Illinoisian advance has less prairie. No extensive prairie tracts occur south of the limit of glaciation.

The only remaining areas of prairie occur along highway and railroad rights-of-way. None of these areas has escaped disturbance. Southern Illinois University has received cooperation from the Illinois Central Railroad in obtaining garden leases for some of the better strips of prairie. Previously these prairies were maintained by the railroad's policy of burning the rights-of-way. Lately, however, the railroads have turned to herbicides to control the "brush and weeds." The spraying has invariably destroyed the natural vegetation and encouraged the growth of noxious weeds. The practice of disking the rights-of-way to control shrubs had a similar effect.

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[1] See Map Section for Illinois locations.

TABLE 1

HALLIDAYBORO PRAIRIE (1970)
Based on 50 Meter Square Quadrats

SPECIES	FREQUENCY
Sorghastrum nutans	92
Euphorbia corollata	76
Helianthus mollis	58
Rubus flagellaris	52
Pycnanthemum flexuosum	38
Panicum praecocius	36
Andropogon gerardi	34
Andropogon scoparius	32
Solidago juncea	28
Fragaria virginiana	26
Tradescantia ohiensis	22
Desmodium sp.	20
Rudbeckia hirta	18
Panicum scribnerianum	16
Eryngium yuccifolium	12

TABLE 2

PERCENT PRESENCE OF ILLINOIS HILL PRAIRIE PLANTS
(Data of Evers, 1955)

SPECIES	PERCENT PRESENCE
Andropogon scoparius	100.0
Erigeron strigosus	94.4
Bouteloua curtipendula	91.6
Petalostemum purpureum	86.1
Penstemon pallidus	83.3
Euphorbia corollata	83.3
Andropogon gerardi	83.3
Verbena stricta	80.6
Kuhnia eupatoroides	80.6
Rhus glabra	72.2
Eupatorium altissimum	72.2
Solidago nemoralis	63.9
Panicum scribnerianum	63.9
Oxalis violacea	63.9
Ruellia humilis	61.1
Aster oblongifolius	61.1

Two of the areas leased by S.I.U. are the Desoto and Hallidayboro prairies north of Carbondale. The quadrat frequencies of species occurring in more than 10 per cent of the quadrats is given in Table I, for the Hallidayboro prairie. These right-of-way prairies have served as teaching areas that are used by several S.I.U. professors. The prairies are also a source of seed that is being used to establish a prairie at the S.I.U outdoor laboratory.

In the spring of 1970, the Illinois Highway Department requested aid in holding two Prairie Symposia, one at Chicago and the other at Effingham. The purpose of the symposia was to provide their men with the background to identify prairies that occurred in their districts adjacent to the highways. Where possible, the more intact of these prairies would be maintained.

In addition to the flatland prairies that extended into Southern Illinois, numerous hill prairies occur. The majority of these prairies occur along the Mississippi River bluffs. Hill prairies are found on steep southwest or west-facing slopes that are underlain with limestone. The depth of the soil mantle varies from a few inches to 20-30 feet of loess. The exposure and topography is such that species typical of drier sites such as little bluestem (Andropogon scoparius) and side oats grama (Bouteloua curtipendula) are common. The most extensive study of hill prairies was made by Evers (1955). The percent presence for species occurring in at least 60 percent of his study areas is given in Table 2.

Recently the Illinois Nature Preserves Commission has acquired the Fults Hill Prairie, near Fults, Illinois, and an adjacent bottomland below the bluff. As can be seen in Table 3, little bluestem and side oats grama are dominant. Some of the interesting plants that occur on this hill prairie include the Missouri brown-eyed Susan (Rudbeckia missouriensis) and wild alfalfa (Psoralea tenuiflora). Another hill prairie that has received protection is the Government Rock Hill Prairie, in Union County. This prairie is within the scenic Pine Hills Recreation Area of Shawnee National Park Forest.

Nearly all the Hill Prairies are being encroached by shrubs and trees. It would appear that a program of prescribed burning will be necessary to maintain many of these prairies in spite of the xeric nature of the site. Those ecologists who wait for another drought cycle like that of the 1930's to kill back the brush may find their prairies have disappeared. Recent correspondence with the Forest Supervisor of the Shawnee indicates that a program of prescribed burning is planned for the Government Rock Hill Prairie.

Work has begun on the response of Southern Illinois prairies to fire. The extent to which fire was a natural force in shaping the vegetation of this region before white settlement is difficult to assess. In many of the parts of the midwest fire was used extensively by American Indians for hunting and other purposes. When white settlers arrived, they stopped the fires and many areas that were formerly maintained as oak savannah or prairie grew up to closed forest.

In Southern Illinois the practice of burning was continued by white settlers in the region until the arrival of the U.S. Forest Service in the 1930's. (Miller, 1920). Fire has obviously been an important factor in shaping the present vegetation. However, one cannot determine conclusively from this evidence whether it is a result of the more recent fires caused by white settlers or if the region has a long history of repeated burning predating White settlement.

However, in the Pine Hills region of the Shawnee National Forest the shortleaf pine appears to be disappearing with the absence of fire that provided the open habitats needed by the shade-intolerant pines for successful reproduction. Furthermore, some of the broader ridges of Southern Illinois support dry forest of post oaks (Quercus stellata) and black jack (Quercus marilandica) with relatively high densities of trees (greater than 200 per acre) but low basal areas (50-75 sq. ft.). Many of these trees are between 30-50 years old; grasses such as little bluestem (Andropogon scoparius) and poverty grass (Danthonia spicata) are the dominant ground cover. Where undisturbed by plowing, the soil has an A_1 horizon of 6-7 inches suggesting a long history of grass cover. The occurrence of other prairie plants such as the Baptisa, rigid prairie golden rod (Solidago rigida) and others suggests a more open nature of the forest at an earlier date. Other areas that were "barrens" at the time of the original land survey have grown up completely to closed forests (Schwegman, 1969).

TABLE 3

FULTS HILL PRAIRIE (1970)
Based on 35 Meter Square Quadrats*

SPECIES	FREQUENCY
Andropogon scoparius	91.4
Bouteloua curtipendula	85.7
Desmodium sp.	54.2
Lespedeza capitata	48.6
Sorghastrum nutans	45.7
Solidago nemoralis	40.0
Petalostemum purpureum	34.3
Psoralea tenuiflora	28.6
Aster azureus	25.7
Andropogon gerardi	22.9
Rudbecki missouriensis	22.9
Houstonia nigricans	20.0
Cassia fasiculata	14.3
Linum sulcatum	14.3
Kuhnia eupatoroides	11.4

*Species with frequency values of 10 and greater

TABLE 4

BURKE BRANCH (1970)*
Based on 44 Meter Square Quadrats

SPECIES	FREQUENCY
Andropogon gerardi	77.3
Cassia fasiculata	63.6
Andropogon scoparius	61.4
Cassia nictitans	56.8
Panicum anceps	47.7
Coreopsis tripteris	38.6
Acalypha gracilens	36.4
Solidago numoralis	34.1
Ambrosia artemisiifolia	31.8
Potentilla simplex	29.5
Sorghastrum nutans	22.7
Euphorbia corollata	22.7
Rudbeckia hirta	20.5

*Following the spring burns, March 16, 1969 and April 5, 1970.

Fire was used to manage a small prairie area (about 1/2 acre) that occurred along the Burke Branch, a small stream in extreme southeastern Illinois. The prairie was being overgrown by trees and was badly enroached by Japanese honeysuckle (Lonicera japonica). Only some general results of this study will be presented here. A paper in preparation will discuss this work in more detail (Anderson and Schwegman, 1970).

Five permanent plots were located and sampled in the fall of 1968. The diameters of all trees (tree species greater than 3.5 inches dbh) on the plots were measured. The seedlings and saplings were also sampled in 1968 before any burning. The area was burned in the springs of 1969 and 1970 and resampled during the summer after each burn. The herbaceous plant and woody stems less than 6 inches tall were sampled in 44 meter-square quadrats, while honeysuckle was sampled by nesting five decimeter-square quadrats within each of the meter square quadrats.

Table 4 gives the percent frequency for species occurring in 20 percent or more of the quadrats. Big and little bluestem are the dominant grasses. Sennas, Cassia fasciculata and Cassia nictitans, are the most abundant herbs. The area is rich and has a total species list of 125 herbs and 26 trees and shrubs on the 1/2 acre. Both woodland and prairie species are found. Some of the characteristic prairie plants such as the Silphium are conspicuously lacking. According to Vestal (1936) barrens lack Silphium as well as some other typical prairie species.

During the first burn a considerable amount of the vining honeysuckle was burned out of the trees; the fire followed up the vines to heights of 10-15 feet. After the first burning (March 16, 1969) there was no decrease in quadrat frequency since much of the honeysuckle readily resprouted. But in 1970, because the fire came on April 5 after the honeysuckle buds had just begun to burst, the frequency of honeysuckle was reduced by about half.

Burning decreased the number of larger woody stems and eliminated completely the seedlings and saplings of river birch and red cedar. Several species including prairie willow (Salix humilis), black walnut (Juglans nigra), and dogwood (Cornus amomum) responded to the fire by vigorous resprouting. Larger stems were killed but the number of smaller stems greatly increased as the result of the sprouting. However, the density of blackberry (Rubus sp.) remained about the same.

The herbaceous plants that showed a marked increase in frequency include several legumes, partridge pea (Cassia fasciculata), sensitive pea (C. nictitans), pencil flower (Stylosanthes biflora), wild bean (Strophostyles leiosperma) and the two goldenrods Solidago memoralis and S. altissima, as well as tall tick seed (Coreopsis tripteris). Ragweed increased after the first year of burning; however, it seemed to be declining after the second burn. Based on studies of the Greene Prairie in the U.W. Arboretum, Madison, it would probably decline in importance, but continue to remain in the prairie (Anderson, 1968).

Fire has also been used as a management tool to aid in establishing a prairie at the S.I.U. outdoor laboratory that was begun in 1968. Big and little bluestem have responded well to the burning; however, the area is at present lacking in many of the forbs that characterize the prairie. Efforts are being made to transplant forbs from endangered areas and also to establish them from seed. One of the factors limiting success to date appears to be the nature of the soil. The soil is a Hosmer silt loam that had been previously under cultivation. It is low in pH (4.0-4.5) with an impervious clay pan. Nevertheless, the big bluestem seems to do very well in spite of the soil and it may well be that other species will show suitable responses.

Preliminary analysis of burned areas on the outdoor laboratory property, has shown a marked increase in legumes and grass flowering culms following burning. An investigation completed the past summer should provide more complete information.

On July 16, 1970, a small strip of prairie along a right-of-way north of Carbondale was burned, apparently by a railroad crew. The prairie began to resprout within a few days in spite of a severe drought. Line transects were used to determine the increase in cover. Results given in Table 5 suggest that the prairie will survive this mid-summer burn.

Spurge (Euphorbia corollata) flowered within 2 weeks after the fire and wild quinine (Parthenium integrifolia) flowered after about 5 weeks. However, portions of the prairie composing less than 5 percent of its area failed to regrow at all. Further studies of summer burning as a method to reduce brush growth may be worthwhile as the fire seemed to be very detrimental to shrubs and small trees. Results shown in Table 5 also indicate that the prairie had stopped growth by early September. The percent bare ground increased slightly from September to October, perhaps owing to sample variation or dieback of herbaceous forbs.

The initial studies of the response to fire of Southern Illinois prairies indicates that they are benefitted by occasional burning. Situated on the Southern end of the prairie peninsula (Transeau, 1935) and receiving fairly high rainfall, it seems reasonable that fire would be necessary in this region to retard invasion by woody plants. Observations of the present day vegetation and historical accounts from adjacent areas suggest that historically fire was an important factor. Only the northern 2/5 of this region had any extensive prairies. However, barrens and small prairie-like openings undoubtedly occurred throughout.

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TABLE 5

SUMMARY LINE TRANSECT
DESOTO PRAIRIE
Percent Cover*

	7/31/70	8/8/70	8/16/70	8/22/70	9/12/70	10/9/70
Andropogon scoparius	37.6	41.4	56.4	56.1	82.2	83.3
Rhus copallina		1.2	1.9	1.9	1.0	.3
Sorghastrum nutans		.1	.8	2.2	2.2	.2
Rhus glabra				1.4	3.1	.5
Euphorbia corollata	.3	.5	1.1	1.6	.7	
Solidago juncea		.1	2.1		1.1	.5
Desmodium sp.	.1	.6	.4	1.4		
Solidago nemoralis	.5	.6	.1	.1	.3	.3
Pycnanthemum flexuosum		.1	.1		1.3	
Asclepias hirtella			.2	.3		
Asclepias tuberosa			.2	.1	.1	
Desmodium sessilifolium			.18	.1	.5	.1
Others	.2	.2	.3	.4	.5	.7
Bare Ground	61.2	40.7	38.2	30.7	13.8	16.0

*Length of line 250 feet. Cover recorded to the nearest inch. The midsummer burn occurred July 16, 1970.

THE USE OF OLD AND ABANDONED CEMETERIES AS PRAIRIE PRESERVES

By

Robert F. Betz

National Sciences Division
Northwestern Illinois State College
DeKalb, Illinois

ABSTRACT

Scattered throughout the various counties of the Middle-west are numerous old settler cemeteries of one-half to two acres which contain remnants of virgin or degraded prairies. In many cases these cemeteries contain the last remaining prairies in the counties in which they occur. Because these cemetery prairies contain the reservoirs of local gene pools, efforts are being made by the newly organized PRAIRIE RESTORATION SOCIETY to locate, restore and fence these valuable plots of ground for future scientific studies and sources of prairie seed.

THE HISTORY OF PRAIRIE PRESERVATION IN IOWA

By

Edward T. Cawley

Department of Biology
Loras College, Dubuque, Iowa

ABSTRACT

While there was early interest in conservation and preservation in Iowa, it was primarily concerned with woodlands. Not until 1933 was preservation of a prairie area mentioned in the Iowa Twenty-Five Year Conservation Plan. In 1944 the conservation committee of the Iowa Academy of Science organized a project on Conservation of Iowa Prairie. In 1946 the Iowa Conservation Commission purchased Hayden prairie, using Fish and Game funds. By 1960, Cayler prairie had been purchased with Fish and Game funds, Kalsow and Sheeder with Land and Water funds.

A subcommittee of the Iowa Academy of Science was responsible for management under a memorandum of understanding with the State Conservation Commission, but the management consisted primarily in allowing farmers to mow for hay, as in other state hunting areas. The Iowa chapter of the Nature Conservancy, formed in 1963, and the Governor's Committee on Conservation of Outdoor Resources in 1965 renewed interest in preservation. The 61st General Assembly formed the Iowa State Preserves System to develop natural, archeological, historical, and geological preserves. Now six prairies are dedicated or otherwise preserved.

Present and future needs include management plans, and action to be taken with the 50 or more prairie areas which have been located in various parts of the state.

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The concept of conservation and preservation has an early history in Iowa. In 1896 the Iowa Academy of Science, as a result of efforts of Dr. MacBride, adopted two resolutions, "one petitioning the Twenty-sixth General Assembly to take some action toward the preservation of our lakes and to maintain some of the original conditions of the State. The other was presented to the Congress of the United States calling to its attention the necessity of further legislation looking to the preservation and rational use of the remaining forests of our country." (Swisher, 1931).

The present concept of preservation was clearly included in the 1927 report of the Conservation Committee of the Iowa Academy of Science which stated "We therefore recommend that this Academy give its decided approval to the policy of setting aside certain portions of the larger parks, and other suitable smaller areas especially in the vicinity of our educational institutions, for the preservation of wildlife and natural conditions. Such areas should be undisturbed as far as possible. To this end we urge that it is necessary that in these areas the policy of making so-called improvements, and particularly the building of expensive highways...be discontinued, and that the money...should be applied to the purchase of additional areas for wildlife sanctuaries."

The major thrust of these early programs, concerned primarily with woodland, was due in part to their scarcity in the Iowa landscape.

It wasn't until the Twenty-five Year Conservation Plan in 1933 that the idea of a prairie preserve was clearly defined (Crane & Olcott, 1933). Little was done with this portion of the plan until 1944. In that year the Conservation Committee of the Iowa Academy issued a report (Hayden, et. al., 1944) on the "Present Status and Outlook of Conservation in Iowa" which formally recommended the implementation of the Twenty-five Year Plan for preservation of a prairie. A sub-committee was formed which, in 1945 and 1946, issued a series of reports and papers (Hayden and Doty, 1945; Hayden, 1946) which included a listing of twenty-two prairie sites in ten counties. In 1946 the first of the prairies was purchased by the Conservation Commission,using fish and game funds. It was named Hayden Prairie, after Ada Hayden who was primarily responsible for the acquisition.

Subsequently three additional areas were acquired as prairie sites: Kalsow Prairie in 1948, Cayler Prairie in 1960 and Sheeder Prairie in 1961. Cayler Prairie was purchased with the fish and game funds, Kalsow and Sheeder with land and water funds. Until recently all four areas have been listed as state hunting areas.

At the time of the purchase of Kalsow Prairie in 1948 the Conservation Commission requested that the Conservation Committee of the Iowa Academy appoint an advisory Committee for advice on management of the prairie areas. In 1949 a memorandum of understanding was subscribed to by the State Conservation Commission and the Iowa Academy, setting up an advisory committee of five members, the prairie project committee: a botanist, a soil scientist and a zoologist; the chief of lands and waters from the Conservation Commission, and the chairman of the Academy's Conservation Committee. (Aikman, 1955). A number of studies relating to management were carried out (Aikman, 1955; Ehrenreich, 1957; Ehrenreich and Aikman, 1963; Hayden and Aikman, 1949), but because of a lack of structured interaction between the Academy and the Conservation Commission, the actual management consisted primarily in allowing farmers to mow the areas for hay, management similar to that followed in other state hunting areas. While mowing has been used to manage prairies, and in fact most of the relic sites were preserved because they had been used as wild hay fields, it does produce some problems including soil disturbance and compaction and removal of seed stock.

The formation of the Iowa Chapter of the Nature Conservancy in 1963 and the formation of the Governor's Committee on Conservation of Outdoor Resources in 1965 brought about a renewal of interest in the idea of preservation, and as a result of recommendations of the Governor's Committee (Haugen, 1965), the 61st General Assembly formed the Iowa State Preserves System to develop natural, archeological, historical, and geological preserves.

In 1968, Hayden Prairie was formally dedicated as the first preserve in the Iowa State Preserves System. Kalsow and Sheeder followed, and the dedication of Cayler is pending. The wording of the Iowa code does not permit hunting on state parks or preserves, and while it was written long before the preserves system was developed, the new system is included under this section. Since Cayler Prairie was purchased with Pitman-Robertson Funds it must be open to hunting, and this conflict is delaying dedication. We hope to amend the code to allow the preserves board to regulate hunting in the preserves system. This would allow for dedication of Cayler Prairie and similar areas, bringing them under the protection of the System and allowing for management primarily as a preserve.

In addition to these areas, a prairie area is included in Gitchie Manitou Preserve which is primarily geological. Linn County has also preserved a sand prairie outside of Cedar Rapids. The Nature Conservancy has leased two areas to protect them from plowing while attempting to acquire the areas.

The Preserves Advisory Board is setting up specific management plans on the areas. Dr. Landers and his students at Iowa State and Dr. Christiansen at Cornell College have completed management studies on Kalsow, Sheeder, and Hayden Prairies.

Paul Kline, the State Ecologist, in consultation with the Conservation department, has written specific plans to be followed by the Conservation department in management of the prairies. The spring and summer of 1971 will allow an evaluation of their implementation by the personnel of the Conservation Department.

At present there are approximately 50 prairies which have been listed either in Hayden's early studies or in the survey taken by the Governor's Committee on Outdoor Resources (Smith and Landers), or reported to the board.

Many of these areas are known only by location; they have not been evaluated and their ownership status is unknown. Future work will require each of these areas to be visited and evaluated for possible preservation.

Since preservation by purchase by the state of all the areas does not seem likely, alternate possibilities must be developed. They could include private and county purchasing followed by dedication into the system. This seems very possible in at least some of the areas if action is taken in the near future.

There is a danger that an attempt to acquire any or all prairies with public funds could meet with opposition from the taxpayers unless a clear rationale for acquisition can be shown. Two guides for selection of areas have been published: Hayden (1944) suggested climatic and topographic regions, while Riechen (1946) modified this with a stress on soil types. Either one would serve as a good starting point in developing criteria for inclusion of areas into the preserves system.

The preserves system in Iowa--by combining protection, management and investigation of prairie --has stimulated the program proposed originally in 1933. With adequate funding for acquisition, management and interpretive studies the "Comprehensive state-wide prairie acquisition program" predicted by Parker (1946), at the time Hayden prairie was purchased, will become a reality. (See Map Section for Iowa Prairie locations.)

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MANAGEMENT ON HAYDEN PRAIRIE: PAST, PRESENT AND FUTURE

By

Paul A. Christiansen

Cornell College
Mount Vernon, Iowa

ABSTRACT

For the past twenty-five years while Hayden Prairie has been under the management of the Iowa Conservation Commission, management has varied from complete protection to burning to biennial haying for the past ten years. Comparison of present frequency data from 1950 and 1970 indicate significant changes are taking place in the vegetation. Populus deltoides, Agrostis alba, and Trifolium pratense have increased in frequency along with a number of vigorous prairie species such as Heliopsis helianthoides and Thalictrum dasycarpum, while several prairie grasses and forbs have decreased. Controlled burning every fourth year is recommended to replace biennial haying as a management procedure.

Topography and Soils

The topography of Hayden Prairie is gently rolling, characteristic of the Iowan Drift area of the Wisconsin glaciation. With minor exceptions the drainage pattern is complete; pot-holes are not present. The loams and silty loams have dark topsoil at least one foot deep and, with few exceptions, moderate to poor internal drainage. According to the Soil Conservation Service, the major portion of the upland soil is Cresco loam with 10-12 inches of moderately dark topsoil and slow water permeability.

Intermediate soils occurring on slopes include Floyd loam, with 10 to 18 inches of dark topsoil and moderate water permeability, while Protivin loam contains more clay, has less topsoil, and less water permeability. Clyde silty clay loam, in intermediate drainageways, has very high organic matter content, 10 to 20 inches of topsoil and moderate to moderately slow water permeability. In upper drainageways is a firm till variant containing more clay than Clyde, while the Ostrander and Waukegon loams in the northeast corner of the Prairie are the only soils with good internal drainage.

Vegetation

Aikman (1955) described the lowest 1/6 of Hayden Prairie as "tall-grass prairie" dominated by Spartina pectinata, Panicum virgatum, Sorghastrum nutans, and Andropogon gerardi. The remaining 5/6 was classified as "true prairie" dominated by Sporobolus heterolepis, Andropogon scoparius, Koeleria cristata, and Stipa spartea. In the most extensive study of the vegetation, Moyer (1953) listed 134 species of which the most frequent upland species were Poa pratensis, Andropogon gerardi, A. scoparius, Phleum pratense , and Sporobolus heterolepis. Three families -- Gramineae, Compositae, and Leguminosae -- contributed 44% of all species present, with 33 families contributing the remaining 56%.

Management

Prior to purchase by the State of Iowa in 1945, Hayden Prairie had been hayed annually for some 80 years and perhaps grazed occasionally. Following acquisition by the State, haying was discontinued and the area was completely protected to allow recovery from long usage. After several years it was determined that complete protection was not producing the desired effect, especially with respect to accumulation of litter (Aikman 1955).

In 1949 plans were made to survey the area (Hayden and Aikman 1949), and Moyer (1953) prepared a survey of Hayden Prairie emphasizing flora, vegetation, and soils. A research project between 1954 and 1958 was concerned with evaluating various management techniques. Controlled burning and mowing were found to be superior to frequent clipping or complete protection (Ehrenreich and Aikman 1963).

In the late 1950's or early 1960's a biennial system of haying was initiated by dividing the Prairie into eight strips of equal area with their long axes oriented north and south. Alternate strips were harvested each year. The hay was sold to the highest bidder who was responsible for harvesting and removing the crop. Haying was delayed until mid-August in most years. Baled hay was usually stacked near the driveway on the north side of the Prairie and removed prior to the next growing season.

Since State acquisition, the Prairie's management has been the responsibility of the State Conservation Commission, which in 1964 adopted a twenty-five year development and management plan, calling for biennial haying and spot spraying to control noxious weeds and invading woody growth.

Evaluation of Management

Two management problems have proven to be troublesome: the invasion by non-prairie species and the accumulation of litter (Aikman 1955). Measurements of litter accumulation (Aikman 1955, Ehrenreich and Aikman 1963, Koelling and Kucera 1965) are in good agreement on amounts present under complete protection. Average of data from five different years is 493 g/m^2 oven-dry weight. In August of 1970 on strips hayed two years previously three replications of litter accumulation averaged 195 g/m^2 while areas hayed the previous year had 174 g/m^2 of litter accumulation. Since these figures are less than half that under complete protection, it appears that litter accumulation has been controlled by biennial haying.

The invasion by non-prairie species has not been prevented and may have been accelerated by haying. Several non-prairie, woody species have been very troublesome, especially Populus tremuloides and P. deltoides. The percent frequency of invading woody species has increased in the last 20 years (Table 1). The ability of these species to produce sprouts from the stem below the level of the mowing accounts for the lack of control by haying; many saplings show that regrowth has occurred several times. Both Moyer's (1953) study and the present one used 1 m^2 quadrats regularly dispersed throughout the upland portion of the prairie. Moyer used 50 quadrats while I used 47.

Percent frequency changes in non-woody species presents a more complex picture. The changes of most concern involve an increase of non-prairie species. Important in this category are Agrostis alba and Trifolium pratense (Table 2). The increase in frequency of a number of prairie species of a weedy nature also indicates disturbance. Some of these are Cirsium discolor, Rudbeckia hirta, Desmodium canadense, and Lathyrus venosus. Two important non-prairie grasses decreased in frequency -- Poa pratensis slightly, and Phleum pratense to a greater extent. A large number of prairie grasses decreased in frequency. These include Andropogon scoparius, Elymus canadensis, Sorghastrum nutans, and Stipa spartea. Forb species showing large decreases in frequency include Achillea millefolium, Antennaria neglecta, Aster ericoides and Comandra umbellata. However, Andropogon gerardi and Sporobolus heterolepis, two of the dominant grasses, showed no change. Other species in this category include Coreopsis palmata, Amorpha canescens, and Lithospermum canescens.

It would be inaccurate to attribute all changes in frequency to biennial haying management. Between the time of Moyer's field work (1950) and my study (1970) a variety of management regimes had been carried out, including: complete protection between 1950 and 1954; a series of burning and mowing experiments between 1954 and 1958; biennial haying from about 1960 to 1969. But haying pursued over a period of approximately nine years must be viewed as having produced the greatest changes in the vegetation.

It should be pointed out that Moyer's results are not to be taken as representative of pre-settlement native prairie in northeastern Iowa. His study was carried out five years after retirement from annual haying, and at a time when concern was expressed regarding the unsatisfactory results of complete protection (Hayden and Aikman 1949). Therefore, the data presented by Moyer should not be considered a goal to be achieved.

A number of minor problems are also associated with the use of biennial haying in management. Since mid-August haying occurs before many species have matured seed, it diminishes the available seed by one-half for those species. Each hay crop also represents a loss in nutrients to the prairie. During the 100 years this prairie has been hayed considerable amounts of nutrients have been lost, much of which would recycle under natural conditions. Continued haying can only worsen the situation.

The operation of haying equipment and the storage of hay on the prairie is another source of disturbance, especially at the north entrance to the prairie where traffic has been concentrated and where baled hay has normally been stored at harvest and later removed. Remains of broken hay bales have sometimes been piled, producing a weed patch when finally removed. In some cases, burning these piles of broken bales has resulted in a very hot fire which destroys the prairie species in the vicinity and allows invasion by weeds.

Management Recommendations

Lack of precise data on the make-up of prairie vegetation before white settlement make it impossible to arrive at an ideal management plan empirically. The most prudent course of action is to attempt to duplicate presettlement conditions as much as possible and monitor vegetation reaction to detect significant changes. To some extent haying has substituted for grazing but for many reasons it is only a poor approximation. Because of their wandering grazing habits introduction of bison as permanent residents would also be unsatisfactory.

Controlled burning, another management tool which duplicates a portion of the presettlement environment, appears to answer many management problems. The studies of Ehrenreich and Aikman (1963) strongly support the use of controlled spring burning as the most effective means of management on Hayden Prairie. They pointed out that controlled spring burning increased productivity, flowering, and seed set. It also eliminated litter to the point that objectionable build-up did not occur for several years. Other studies support their conclusions (Curtis and Partch 1948, Kucera 1960, Kucera and Ehrenreich 1962, Kucera and Koelling 1964).

It is recommended that biennial haying be abandoned as a management procedure and be replaced by controlled burning. The Prairie should be divided into four to six units separated by paths mowed several times each season and wide enough to serve as fire lanes. These units should be of approximately equal size and contain both upland and lowland areas where possible. Each unit should be burned every fourth year except in the initial phases of the plan when burning should be every second year until woody plant invasion is no longer a problem. A plan of burning should protect adjacent unburned units to maximize reinvasion of burned units by organisms which are destroyed by fire. Also, animals which survive the fire but require cover can move to these adjacent unburned units (see Riechert and Reeder, 1970; Schramm, 1968).

Controlled burning should be carried out between 1 March and 15 April. A unit which cannot be burned on schedule should be burned the following year along with that year's scheduled unit(s). Lighting and management of fires should be conducted in such a manner that heavy equipment is not required on the prairie. Most or all of the burning can be done by backfiring, starting at the downwind edge of the unit in the tall vegetation at the edge of the firelane. The fire in the short grass of the firelane can be extinguished with water sprayers or slappers. If controlled burning does not eliminate Populus spp. and other invading woody vegetation, mowing, after seed set of prairie species is complete (about 1 October) is recommended. This mowing should be confined to areas where trees are present. Because such areas will be burned within one or two years, clippings will not have to be removed.

These recommendations have been accepted by the Preserves Advisory Board and the Conservation Commission. The first units will be burned in the spring of 1971. It must be emphasized that no recommendations whould be followed blindly. Because of the interest and diligent work of a number of far-sighted people, Hayden Prairie has been preserved, and thoroughly studied. It will be depended upon to serve as an example of prairie for generations far into the future. The management of this

area to preserve it in an approximation of its priatine condition based on past research and revised periodically in the light of further knowledge takes on formidable proportions. Personnel and funds for essential continued monitoring and research are indispensible if this challenge is to be met.

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TABLE 1

Change in percent frequency of invading woody species on Hayden Prairie between 1950 and 1970.

Species	1950[a]	1970
Acer negundo	0	2.1
Populus deltoides	0	19.1
Populus tremuloides	4	2.1

[a]From: Moyer 1953.

TABLE 2

Percent frequency changes during the past 20 years on Hayden Prairie, Howard County, Iowa

Species increasing in % frequency	1950[a]	1970
Agropyron trachycaulum	0	8.5
Agrostis alba[b]	12	31.9
Panicum implicatum	0	36.1
Cirsium discolor	8	44.7
Heliopsis helianthoides	14	31.9
Parthenium integrifolium	0	17.0
Ratibida pinnata	6	14.9
Rudbeckia hirta	0	38.3
Taraxacum officinale[b]	0	6.4
Desmodium canadense	2	19.2
Lathyrus venosus	2	21.3
Psoralea agrophylla	0	4.3
Trifolium pratense[b]	2	10.6
Cicuta maculata	10	38.3
Dodecatheon meadia	0	8.5
Galium borale	24	66.0
Lobelia spicata	0	10.6
Oxypolis rigidior	0	12.8
Phlox pilosa	4	23.4
Polygala sanguinea	0	21.3
Populus deltoides[b]	0	19.2
Rosa suffulta	14	48.9
Thalictrum dasycarpum	22	61.7

Species with little change in % frequency	1950[a]	1970
Andropogon gerardi	94	95.8
Calmagrostis candensis	4	6.4
Muhlenbergia racemosa	20	14.9
Poa compressa[b]	14	21.3
Spartina pectinata	4	2.1
Sporobolus heterolepis	82	80.9
Cacalia tuberosa	6	2.1
Coreopsis palmata	24	19.2
Silphium laciniatum	6	2.1
Amorpha canescens	44	46.8
Eryngium yuccifolium	12	10.6
Lithospermum canescens	32	48.9
Populus tremuloides[b]	4	2.1
Spirea alba	2	4.3

Species decreasing in % frequency	1950[a]	1970
Andropogon scoparius	88	59.6
Elymus canadensis	28	0
Koeleria cristata	12	2.1
Panicum scribnerianum	26	10.6
Panicum virgatum	26	2.1
Phleum pratense[b]	82	48.0
Poa pratensis[b]	90	76.6
Sorghastrum nutans	62	36.1
Stipa spartea	44	17.0
Achillea millefolium	70	12.8
Antennaria neglecta	34	4.3
Aster ericoides	42	4.3
Liatris aspera	8	2.1
Liatris pycnostachya	16	4.3
Lespedeza capitata	14	4.3
Petalostemon purpureum	16	8.5
Vicia americana	24	2.1
Comandra umbellata	42	25.5

[a]From: Moyer 1953.

[b]non-prairie species.

MANAGEMENT OF KALSOW PRAIRIE

(From a report on the vegetation of Kalsow Prairie prepared for the Iowa State Conservation Commission and Iowa Preserves Advisory Board, June, 1970, under direction of Roger Q. Landers)

By

Mary S. Richards

Department of Botany and Plant Pathology
Iowa State University, Ames, Iowa

ABSTRACT

Since 1956, half of the Kalsow Prairie Preverve has been experimentally burned with good results in comparison to the undisturbed control areas, while mowing to create fire lanes and the use of heavy equipment ruts and damages vegetation. Surrounded by cultivated lands and pasture, this prairie is invaded by no woody species and by annual weeds only where windblown soil from adjacent fields periodically covers a strip of prairie along the edge up to 60 feet wide. Recommendations are made to use spring fires with no mowing for future management and to use interpretation and minimal "development" to guide public use.

Introduction

Because it is impossible to know completely and to duplicate exactly the environment under which the prairie developed and survived for centuries, any management plan must be examined periodically to determine if it is, in fact, maintaining the prairie in a condition similar to our understanding of the original presettlement state. One means of assessing the effect of current management practices is to compare the composition of the vegetation as determined by studies made in different years, as has been done on Kalsow Prairie by Moyer (1953) and Brotherson (1969); however, we have no specific information for an earlier time with which we can compare. Some changes in composition which took place during the 16-year interval suggest that different management is needed.

Another indication of the success of management is an evaluation of the vigor and productivity of the prairie species in comparison with the amount of duff and litter material on the ground. In 1968 the ash-free, oven-dry weight of the standing vegetation averaged 2.34 tons per acre while the litter comprised 3.8 tons per acre. Studies by Ehrenreich and Aikman (1963) show that vigor of prairie species is reduced when the weight of accumulated litter is greater than the weight of the standing vegetation at the end of the growing season.

Control of litter accumulation is essential in a self-perpetuating prairie ecosystem. Curtis and Partch (1950) concluded that litter removal was the most important factor in the inducement of flowering in Andropogon gerardi. Generally, increasing accumulations have been shown to cause an overall stagnation of the prairie community. Studies on Kalsow Prairie in 1968 (Richards, 1969) showed that the removal of litter by burning caused a substantial increase in flowering and production for many species. While mowing stimulated some species it generally was not as effective as burning.

Current Management

Following an experimental fire in April, 1969, a dramatic increase in flowering was noted during the growing season. Although no formal sampling was done, a positive response was obvious. Mowing operations to create a fire lane prior to the burn caused considerable local damage to the vegetation. The equipment was too heavy for the soft moist soil, and tended to bog down and make deep ruts. A similar situation occurred when a water tank truck was used to patrol the lane during the fire. Since 1956, when a wild-fire inadvertently swept the prairie, approximately half the preserve has been burned experimentally. On the remaining half, the litter has not been disturbed.

At this time there is no real problem caused by the invasion of woody plants or annual weeds on most of the prairie. Some weeds found on freshly disturbed Mima mounds and ant hills are in the course of normal succession soon replaced by the perennial plants of the area. At present the activity of pocket gophers is not considered to be a threat to the prairie vegetation; however, it is possible that they could become destructive in the future if their population were to increase significantly. Two small patches of Canada thistle are established, but they are not spreading at this time.

A more serious situation is the distrubance caused by the influx of blowing soil along the south and west fences. A strip of prairie as wide as 60 feet in some places is affected by the deposit of dust, which results in the appearance of a dense stand of field weeds for several years until the prairie species replace them. Usually a new deposit of dust every few years perpetuates the weeds.

Recommended Guides for Management:

I. Fires: Studies by Ehrenreich and Aikman (1963) and Richards (1969) show that early spring burning is an effective management technique. Litter is controlled without damaging the soil or vegetation; and productivity, flowering and seed set of the native species are increased. Bluegrass and annual weeds are significantly set back, and woody plants are controlled.

It seems unnecessary to partition Kalsow Prairie in any way for fire control. To break it up would destroy much of the natural beauty of one of our finest prairie preserves. Judicious use of backfires and caution make any mowing operations extraneous. The preserve is surrounded by plowed fields in the spring, so even if a fire should somehow flare out of control, it would be contained at the boundary.

It is suggested that half of the prairie be burned every three years, although this should not be considered mandatory. If conditions are not right during the preferred time, fire can be postponed until the following year. A natural drainage system runs in a North-South direction across the prairie, providing a natural firebreak (Figure I). All areas east of it could be burned one year, all areas west of it burned three years later. This would mean litter would accumulate for about six years before being removed. Burning the entire preserve at once is not suggested.

Burning should be done sometime during, but no later than, the first three weeks of April. During this time the bluegrass in the formerly grazed area should be green, but the native species should not have emerged. If shoots appear early during a proposed burn year, the fire should be postponed until the following year.

Lighting and control of the fires should be done by crews on foot, with no vehicles allowed on the prairie. The following techniques are suggested:

1. Headfires should run from the drainage toward the fence whenever possible.

2. Backfires should be ignited first to burn against the wind and create a fuel-free area where the fire is to stop.

3. Backfires and headfires should not come together in such a way that they enclose an unburned area and trap the wildlife by fire on all sides. One side should be left open as the fires meet (Figure I).

4. Small unburned patches should not be ignited by hand because they offer valuable cover for wildlife during the critical time between the fire and the regrowth.

At this time available information is inadequate to dictate a permanent burning policy. As more information is gained on the dynamics of the prairie ecosystem, this policy should be adapted to conform with it.

II. Buffers and Boundaries: Herbicides should not be used on the annual weeds growing along the south and west fences. As long as there is an influx of soil, the disturbance community will exist. To alleviate this situation, it is suggested that buffer strips of approximately 50 feet be purchased or easements be obtained along these fences to be planted for wildlife cover or left in crop stubble throughout the winter months. This would largely eliminate the problem of soil blowing onto the prairie. The current disturbed areas would gradually revert back to prairie vegetation by natural succession. Because of the inherent stability of the native vegetation and the inability of annual species to invade except in disturbed areas, the buffer strip would pose no threat to the prairie.

An extension of the drainage system extends into several acres of hayfields south of the prairie. This land - mowed but never plowed - would be an appropriate addition to the preserve if it could also be purchased.

III. Pest Plants: Stronger control measures may have to be taken against the Canada thistle if it begins to spread. Christiansen (1969) indicated that this species may react with renewed vigor to fire, so that spraying would be necessary to control it. If so, absolutely no broadcast spraying should be done, as many prairie species are extremely sensitive to herbicides. Only the more careful spot treatments are recommended if spraying should become necessary.

IV. Motor Vehicles: No management practices requiring motor vehicles or heavy equipment are necessary. All traffic should be prohibited.

V. Hunting: Currently, hunting is allowed. Since most of this activity occurs after the plants have matured, it should not cause any serious damage. However, if the hunting pressure does increase significantly in the future, the Preserves Board should reserve the right to limit it.

VI. Public Use: Several improvements are suggested to increase the utilization of Kalsow Prairie:

1. An attempt should be made to procure the uncropped land adjacent to the northeast corner of the preserve, to provide a parking area for visitors and a site for a small information board. The area is adjacent to a railroad right-of-way which contains an abundance of prairie species. A sign, calling attention to this fact, might read, "Along the adjacent RR tracks grow a variety of native prairie plants. Besides designated preserves, old cemeteries and RR rights-of-way are the few sites where these species may still be found." Should this line be abandoned in the future, all possible efforts should be made to purchase the land. Since the nearby town of Manson maintains a large park, no other visitor facilities are necessary here.
2. The formerly grazed area in the northwest corner of the prairie abuts the road where many visitors first stop. The abundance of bluegrass and Canada goldenrod gives a false impression of the true nature of the preserve. To change this impression, a sign explaining that this area has been grazed in the past, and is now being left to revert to native vegetation, might read, "This 40-acre portion of the preserve was heavily grazed prior to 1949. It is now being allowed to revert to native vegetation. As you walk into the area, you will find an increasing number of the prairie species which are slowly forcing out the pasture plants."
3. A small path leads into the preserve from a gap in the fence at the northeast corner. It soon splits, one branch going to the center of a small pothole, the other branch circumventing it. If extended somewhat into the prairie, this path could serve as the basis for an interpretive leaflet that might be available at the parking area or obtained at some central location in Manson. Little should be done to maintain the path; it should not be mowed. A few people walking the length of the route a couple of times would be sufficient traffic to mark the way. Once established, normal use would keep it visible. A second path leads into the preserve from the southeast corner, providing a ready made route for visitors to certain areas. Most will enter only a short way on the established paths before returning to their cars. The few who choose to go farther will do little harm.

4. Interpretive leaflets should be available to the public. If possible some arrangement should be made to have leaflets available at the prairie. Other wise, there should be a notice posted near the main entrance directing visitors to a source nearby or in Manson.

5. So that this native community and others may be studied and understood by students and interested citizens, the information contained in this report and others should be made available to educators and the public at no cost or for a nominal charge. Details for obtaining this information should be given in the interpretive leaflet. Understanding cultivates an appreciation which will benefit the future of all preserves.

6. It is of utmost importance to keep Kalsow Prairie as natural as possible, and free from the artificial trappings so often imposed by man in an attempt to "improve" a natural area.

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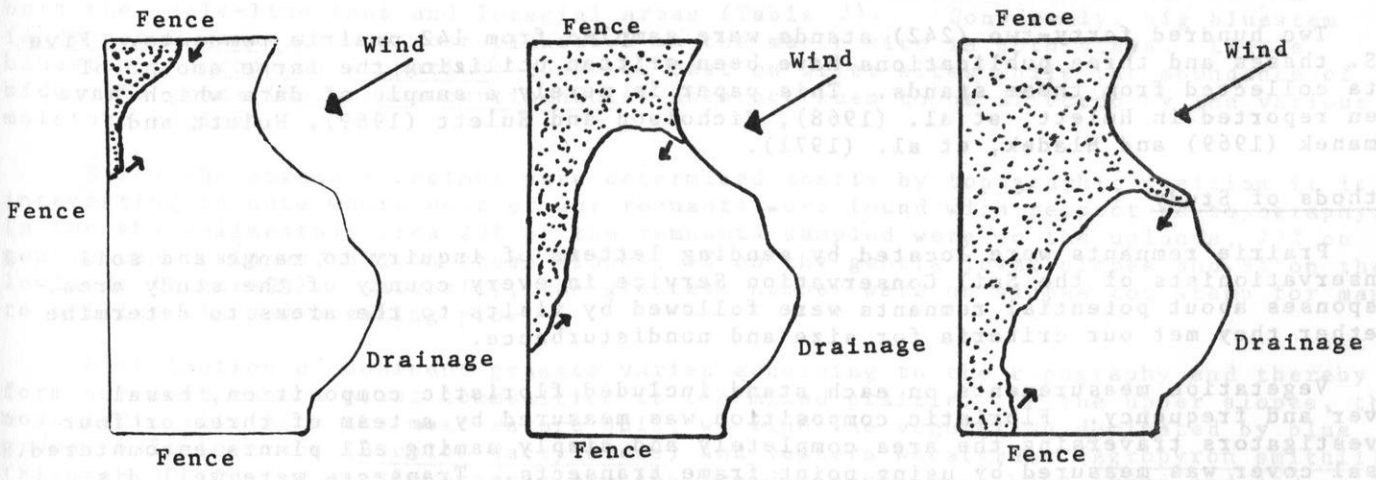


FIGURE I

Suggested Pattern for Burning

A SURVEY OF SOME REMNANT PRAIRIES OF THE CENTRAL GREAT PLAINS

By

G.W. Tomanek

And

G.K. Hulett

Department of Biology
Fort Hays State College, Hays, Kansas

ABSTRACT

A National Science Foundation Grant made possible a study of 142 prairie remnants which included 242 separate stands in western Kansas, western Nebraska, eastern Colorado and southeastern Wyoming. Floristic composition of stands was determined and related to various habitat characteristics. The geographical region was divided into land resource areas (Austin, 1965) which were used as a foundation upon which the undisturbed prairie remnants could be characterized and compared. Some of the data have been analyzed to determine (1) factors responsible for prairie remnants, (2) relative importance of plant families, (3) grass and forb species distritubion in relation to moisture regimes, topographic characteristics, soils, and other habitat factors, and (4) distribution of woody vegetation in prairie remnants.

Introduction

Remnant stands of native prairie are rapidly disappearing as a result of overgrazing, cultivation, building and road construction and various other types of man's activities. A survey of prairie remnants in the Central Great Plains was conducted from 1964 to 1967. The Central Great Plains, as defined by the authors, included western Kansas, western Nebraska, eastern Colorado and southeastern Wyoming. However, most of the prairie remnants studied were located in Kansas and Nebraska (Figure I). A prairie remnant is defined as an area of natural grassland that has been relatively free of human disturbance such as grazing of livestock, mowing, dusting and other similar activities for at least 20 years.

The purpose of this investigation was to analyze the distribution and species composition of these prairie remnants. The study was initiated to obtain information for future ecological studies and to provide a permanent record and inventory of the structure of such grasslands.

Two hundred forty-two (242) stands were sampled from 142 prairie remnants. Five M.S. theses and three publications have been written utilizing the large amount of data collected from these stands. This paper is merely a sample of data which have been reported in Hulett, et al. (1968), Nicholson and Hulett (1969), Hulett and Tomanek (1969) and Hladek, et al. (1971).

Methods of Study

Prairie remnants were located by sending letters of inquiry to range and soil conservationists of the Soil Conservation Service in every county of the study area. Responses about potential remnants were followed by visits to the areas to determine whether they met our criteria for size and nondisturbance.

Vegetation measurements on each stand included floristic composition, basal cover and frequency. Floristic composition was measured by a team of three or four investigators traversing the area completely and simply naming all plants encountered. Basal cover was measured by using point frame transects. Transects were well distributed throughout each stand and a minimum of 1000 points were read per stand. Frequency was measured by using 40-1/4 meter quadrats, rectangular in shape, on each stand and every species in each quadrat was recorded.

Many habitat characteristics were noted and recorded such as slope exposure, position on the slope, degree of slope, amount of mulch, amount of dusting, and degree of mammal disturbance. Topographic moisture classes (dry, mesic and wet) were also determined. Soil samples were taken from 0-6 inches in depth to determine texture, % rock, pH, organic matter, phosphorus and potassium.

Results

Large amounts of data were collected from these 242 prairie remnant stands but only a small portion of it is reported in this paper.

A number of factors were found to be responsible for certain natural areas being protected from disturbance for many years. Road construction was found to be responsible for 39% of the remnants studied (Table 1). Frequently small areas are cut off by road construction from a main pasture and it is not feasible to graze the area any longer. Man not only destroys and disturbs the prairie but sometimes certain areas may be preserved by his activities, even though unintentional. However, some prairie remnants were found around reservoirs, game refuges and educational institutions that were intentionally preserved. These, however, constituted less than 10 percent of the total. Other factors responsible for preservation of prairie remnants were insufficient water supply for livestock, rough topography, uncultivated field corners, fenceline right-of-ways, cemeteries and undeveloped sectionline roads.

Two areas were studied rather intensively, the Shale-Limestone Area and the Loessial Hills, which are both subdivisions of the Rolling Plains and Breaks Resource Area. Hladek et al. (1971) reported on the shale-limestone studies in Central and Western Kansas while Hulett, et al. (1968) reported on the loessial hills along the northern border of Kansas and Southern Nebraska. (See Figure I).

Plant families most commonly found in these two studies were Gramineae Compositae, Fabaceae, and Euphorbiaceae (Table 2). These four families comprised more than one-half the total species and have been found quite important on many prairies (Steiger, 1930; Curtis and Greene, 1949; Whitford, 1958; Dix and Butler, 1960). The number of species per stand varied from 30 on wet mesic to 56 on very dry stands.

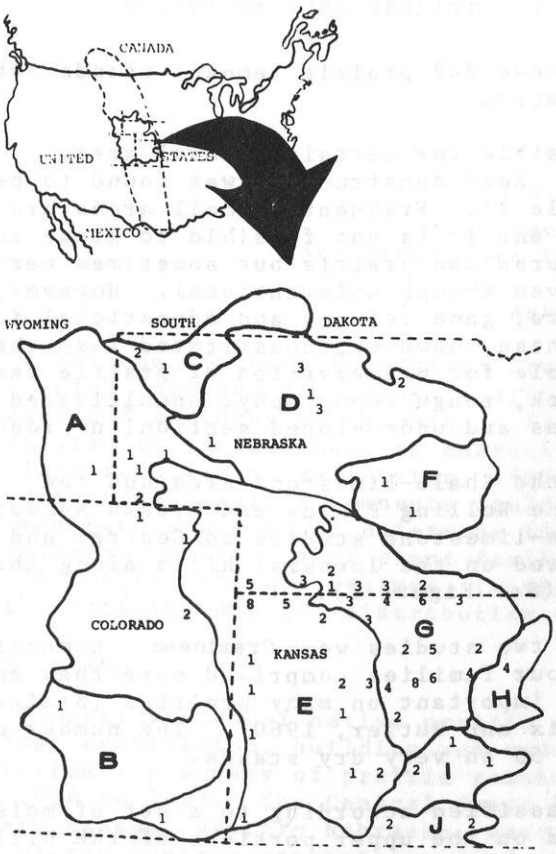
As indicated earlier various stands were classified according to a set of moisture regimes. A very dry stand was usually found on the upper portions of the hill with considerably less moisture accumulation than run-off. Our dry-mesic stands were located where there was a moisture accumulation about equal to the amount of moisture that ran off and mesic stands were located so that moisture accumulation exceeded the amount lost by run-off.

Utilizing these three moisture regimes for the remnants in the shale-limestone and loessial areas we found considerable variation in the distribution of dominant species. For example, blue grama (Bouteloua gracilis), a drought resistant species, was more plentiful on the very dry site and least plentiful on the mesic site on both the shale-limestone and loessial areas (Table 3). Conversely, big bluestem (Andropogon gerardi) was most plentiful on the mesic site in both areas. Little bluestem (Andropogon scoparius) competes best on drier sites while the abundance of side-oats grama (Bouteloua curtipendula) does not seem to be affected by the various moisture regimes.

Since the moisture regimes were determined mostly by topographic position it is interesting to note where most of our remnants were found with respect to topography. In the shale-limestone area 20% of the remnants sampled were on the uplands, 27% on gentle upper slopes, 39% on steep slopes, 6% on the gentle lower slopes and 8% on the lowlands (Figure II). Naturally, the greatest number were on slopes too steep for man to utilize his sod breaking plow.

Distribution of dominant grasses varies according to the topography and thereby form our most common plant communities in the mixed prairie. On the upper slopes, the most xeric site with the most mature soil, we find the vegetation dominated by blue grama, buffalo grass (Buchloe dactyloides) and western wheatgrass (Agropyron smithii) (Figure III). On the gentle upper slope the two dominants were blue grama and side-oats grama with smaller amounts of the bluestems but the steep slopes we found dominated by little bluestem, side-oats grama and hairy grama (Bouteloua hirsuta). The lower slopes were dominated by the bluestems and side-oats grama while the lowlands had three dominants, big bluestem, switch grass (Panicum virgatum) and western wheatgrass. Distribution of species according to topography was similar in the loessial area (Table 4).

Nicholson and Hulett (1969), utilizing some of the data collected from these prairie remnants, developed a system by which they fixed an importance value (IV) to the various species by multiplying the % composition by the % presence. Blue grama



LEGEND

A Central High Plains, Colorado, Wyoming, Nebraska

C Mixed Sandy and Silty Tableland, Nebraska

D Nebraska Sand Hills

E Central High Tableland, Kansas, Nebraska

F Central Nebraska Loess Hills

G Rolling Plains and Breaks, Kansas

FIGURE I

Outline of Major Land Resource Areas With The Number and Approximate Location of Remnant Stands (after Nicholson and Hulett, 1969).

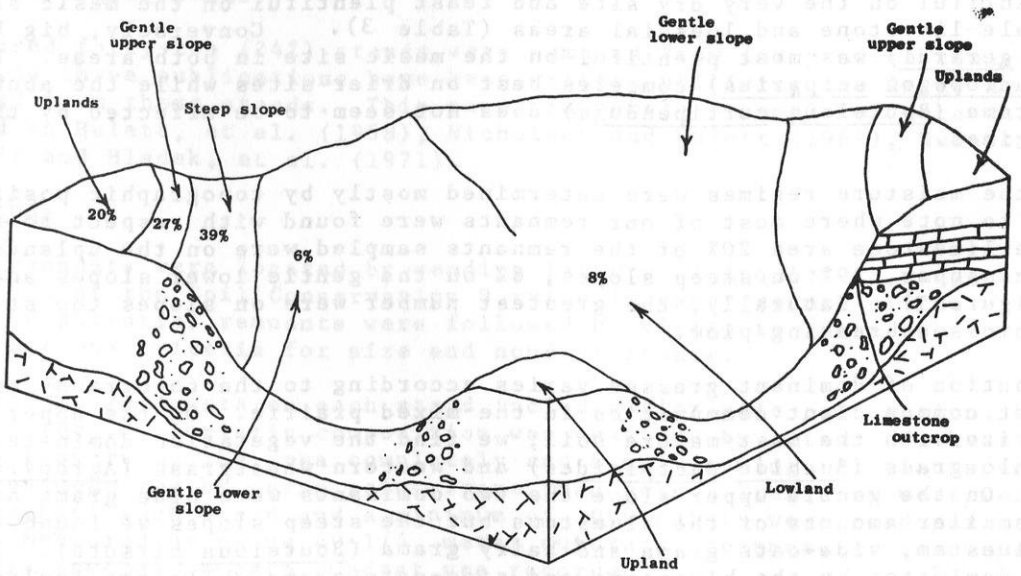


Fig. 2. A hypothetical block of the Mixed Prairie landscape in shale-limestone prairies showing percentages and relative position of stands.

FIGURE II

A Hypothetical Block of the Mixed Prairie Landscape in Shale-limestone Prairies Showing Percentages and Relative Position of Stands.

Table 1: Factors Responsible for Remnant Grasslands in the Central Great Plains.

Factors	% of Stands
Road Construction	39.4
Farming Inaccessability	21.2
Insufficient Water Supply	12.6
Double Fence Rows	10.2
Undeveloped Road Rights of Way	6.0
Recreation Areas	4.0
Cemeteries	2.3
Research Reserves	1.4
Others	2.9
	100.0

Table 2: Family Composition of Prairie Remnants in Shale-limestone and Loessial Areas.

Family	% Composition Shale-Limestone	Loessial
Gramineae	20.0	23.5
Compositae	22.4	21.0
Fabaceae	8.2	10.3
Euphorbiaceae	5.0	5.6
Chenopodiacae	2.0	5.4
Onagraceae	3.7	3.4
Cichoriaceae	2.2	2.9
Cactaceae	1.3	2.8
Boraginaceae	1.9	2.1
Asclepidaceae	2.2	1.8
Lamiaceae	2.9	-
Ambrosiaceae	2.0	-

Table 3: Percent Composition of Principal Grasses on Various Moisture Regimes in Shale-limestone and Loessial Prairie Remnants.

Species	Very Dry		Dry		Dry Mesic		Mesic	
	S-L	Lo	S-L	Lo	S-L	Lo	S-L	Lo
Blue Grama	8	20	3	31	4	13	2	4
Side-oats	18	27	18	29	19	24	8	32
Little Bluestem	39	32	25	10	16	13	8	7
Big Bluestem	14	1	35	10	46	31	77	24

Table 4: Mean Absolute Frequencies Relation to Topographic Position in Loessial Hills.

Species	Level Upland	Steep Upper Slope	Gentle Upper Slope	Gentle Lower Slope	Lowland
Blue Grama	62	34	40	50	13
Side-oats Grama	15	84	70	73	55
Little Bluestem	8	64	32	17	20
Big Bluestem	33	17	29	27	51
Western Wheatgrass	T	5	8	13	55
Needle-and-Thread	11	11	9	12	-

Table 5: Importance Values (Percent Composition x Percent Presence).*

Species	Nebraska Sand Hills	Central High Plains	Mod Sandy & Silty	Central High Tableland	Rolling Plains & Breaks	Central Nebraska Loess Hills
Blue Grama	4.8*	66.0	23.1	40.1	3.5	12.3
Western Wheatgrass						42.2
Little Bluestem	12.0				10.3	
Buffalo grass				5.3		
Sand Reedgrass	12.4					
Sedges	27.6	7.6	33.3		3.1	6.3
Sand Bluestem	5.3					
Needle-and-Thread	7.8	7.0	26.8			
Side-oats Grama					19.0	3.9
Big Bluestem					27.3	13.7
Sand Lovegrass	3.4					
Sand Dropseed	3.0					

*Only importance values of over 3.0 included

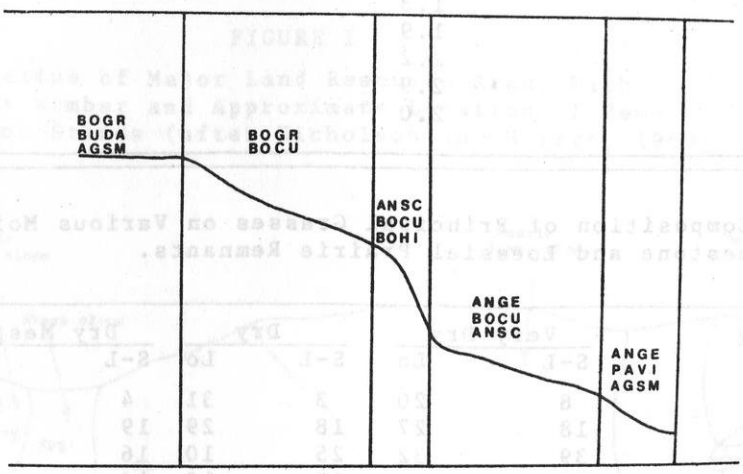


FIGURE III

Distribution of Plant Communities in the Shale-limestone Area of the Central Great Plains. BOGR-Bouteloua gracilis, BUDA-Buchloe dactyloides, AGSM-Agropyron smithii, BOCU-Bouteloua curtipendula, ANSC-Andropogon scoparius, BOHI-Bouteloua hirsuta, ANGE-Andropogon gerardi, PAVI-Panicum virgatum.

was the only species with an IV of over 3.0 in all six Land Resource Areas (Austin, 1965). It was least important in the Nebraska Sandhills and most important in the Central High Plains (Table 5). Although western wheatgrass occurred in all six areas it was important only in the Central Nebraska Loessial Hills. Buffalo grass was important on only the Central High Tableland but it is much more important on grazed prairies in many of the Land Resource Areas (Tomanek and Albertson, 1957). Sedges, which were lumped together, were important in five of the six resource areas while sand lovegrass (Eragrostis trichodes) and sand dropseed (Sporobolus cryptandrus) were important only in Nebraska Sandhills. Needleandthread grass (Stipa comata) was important in Nebraska Sandhills, Central High Plains and the Moderately Sandy and Silty Resource Areas. Side-oats grama and big bluestem were important in the Rolling Plains and Breaks and Central Nebraska Loessial Hills.

All of the examples used in this paper refer to dominant plants while some of our most interesting correlations were found among plants that were not dominant, or even the distribution of plants that were rare. Sometimes these rare plants told us more about the habitat than the more tolerant, widely distributed, dominant plants. In fact, Hladek, et al. (1971) named their communities after uncommon but indicative species rather than the dominants.

The large amount of data collected in this study is still being analyzed and it is hoped that a number of other ideas or opportunities for further research may result. The study does illustrate that a number of prairie remnants do still exist but they are disappearing rapidly. It behooves us all to make every effort to record the flora and fauna of these remnants but also to find a way of preserving as many as we can of the different types. Much work remains to be done on these remnants going from the descriptive aspect (included in this study) to a more functional approach examining such items as energy relations and nutrient cycling in selected grassland ecosystems.

ACKNOWLEDGMENTS

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TALL GRASS PRAIRIE IN COLORADO AND ITS AESTHETIC VALUE

By

W.H. Moir

Department of Range Science
Colorado State University, Fort Collins, Colorado

ABSTRACT

Tall grass prairies were once commonplace in Colorado, along the Front Range foothills and adjoining the Black Forest. Today only vestiges of the original prairies remain, and they too are rapidly succumbing to the onslought of the developers' bulldozers.

Five relict prairies near Boulder contributed to ecological description of Colorado prairies on deep, clayey soils. The prairies are floristically diverse, containing over 180 plant species, and are rich in western elements of the vascular flora. With cattle and horse grazing, these prairies can change to mixed-grass and shortgrass prairie types. Intense grazing has caused the loss of vast prairie areas in Colorado.

Prairie areas in the Boulder-Denver-Colorado Springs metropolitan complex are in critical danger of extinction. However, the residents of this area have invariably expressed interest in seeing such natural vegetation. Many have said that they were amazed to learn of tall grass prairies still existing in the United States, much less in their own back yard! The cultural, educational, and aesthetic worth of prairies can be of enormous benefit to the over 2 million residents of the greater Denver area.

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Tall grass prairie? In Colorado? "Come on, you're kidding!"

So exclaim many of the residents of the greater Denver area when I tell them about their exciting prairies. "I thought the tall grasses were plowed up decades ago and converted to corn in the Midwest." At present few Coloradoans are aware that tall grass prairies still exist in the U.S., much less in their own backyard!

Tall grass prairie, true prairie, or simply prairie was once commonplace in eastern Colorado. Early botanists described Colorado prairies resembling those of Illinois, Iowa, or Missouri along the fringes of the Black Forest between Colorado Springs and Denver (Shantz 1906, Livingston 1952) and in the mountain front foothills near Boulder (Vestal 1914, Dodds et al 1908, James 1930, Branson et al 1965). Doubtless Zebulon Pike unknowingly beheld Colorado prairie long before he perceived the famous peak he said would never be climbed. Except in a few technical publications, no one has ever bothered to document the existence and beauty of this wonderous vegetation that nearly fringes the entire "Great American Desert." And today the tall grass prairies of Colorado are nearly extinct and almost forgotten.

Yes, prairies can still be found in Colorado, but you've got to hunt for them. Why, you ask, this excitement about tall grass prairie? Perhaps, as Jim Wilson, a prairie addict from Nebraska says, "This complex, brawling, tension-ridden world alarms us and we find comfort in the timeless, reassuring presence of the Prairie." There is little doubt that the prairie is indeed something very exceptional. Consider, for example, the Colorado prairie. The original prairies were resplendent with 5- or 6-foot waving stems of big bluestem, switchgrass, yellow indiangrass, porcupine grass, and hosts of other grasses of shorter stature. Well over a hundred different kinds of bright flowers emblazoned these waving fields from April through October. People are hunting for prairies because they are phenomenally rich and diverse biological communities, and Colorado prairies are no exception.

Yet, our Colorado Prairies are something uniquely western, as shown by floristic studies from 5 relict prairie areas near Boulder (Table 1). The flowering year begins in profusion as early as April. Sand lilies, pasque flowers, and yellow violets contribute to early spring color. In May the mariposas, arnicas, lupines, and puccoons may explode with glorious hues, either singly, each species dominating for the moment with its own color, or in combination of multicolor spectacle. June is the time for gaillardias, paintbrush, golden banner, cinquefoil, blue flax, and

many others. In late July and August there is a brief hiatus in prairie color, for now the grasses have achieved considerable height, and their waving stems are a sea of motion. Among the grasses, however, both white and purple petalostemons, Navaho tea, golden aster, and other bright flowers occur. By september the grasses have mostly completed their year's cycle. The soils are becoming dry, and the clear, cool days of Colorado's indian summer have arrived. This is time to find asters, goldenrods, blazingstars and even the rare western prairie gentian in full flower. The big bluestem, yellow indiangrass, and switchgrass are turning gold and red. Skunkbush is brilliant orange. The prairie autumn in luxuriant chromas provides a fitting completion to the colorful procession of the prairie year.

Our Colorado prairies are a wealth of plant and animal life. One botanist (Livingston 1952) listed over 140 flowering plant species on prairies of the Arkansas-Platte Divide. This is doubtless an underestimate of plant richness, for I have tallied over 180 vascular plant species in prairie remnants near Boulder. Some prairie dwellers are quite rare. The great blue lobelia reaches us from prairies of Illinois and Iowa and is an exceptional "discovery" in prairie areas south of Denver. In foothill prairies near Boulder are the rare indigo and Jersey tea. This latter shrub was much sought for by New Englanders after the Boston Tea Party episode, for its leaves and flowers make an excellent sweet beverage. The bird watcher can have his day in the Colorado prairies, too. Many birds are also found in the more widespread mixed and shortgrass prairies, but the secretive grasshopper sparrow is a species that I associate with the tall grasses. Its insect-like "buzz-buzz-buzz-zz-zz" reveals its nesting territory somewhere in that dense foliage.

The prairie is normally a vegetation of the sub-humid forest borders of eastern North America. It occurred there in a region of 20-50 inches of yearly average precipitation that is now, as we know, mostly cornland. In Colorado, too, the prairie is mostly a forest border vegetation; in this case ponderosa pine is the main forest type. Prairies exist here on sites where soil characteristics or topography compensate for the low rainfall. Near Boulder the prairie remnants are found on deep, clayey soils (Table 2). Such soil can store enormous quantities of water and is an effective resevoir for the year's precipitation. Although Boulder's mean annual precipitation averages only 18.5 inches, virtually all of this can be stored for spring and summer prairie growth in the deep clayey profiles. Along the Black Forest margins, on the other hand, are areas of deep, sandy soil (Livingston 1952). Such soils effectively trap light rains as well as torrential cloudbursts of summer. Rapid percolation of water into sandy soil enables water to be effectively used by the deep rooted prairie plants (Williams and Holch 1946, Branson et al 1965).

Much of the original Colorado Prairie disappeared as the result of livestock grazing. Much of the prairie flora is ice cream to cattle and horses. Livestock long confined to luscious, tasty pastures of bluestem and other very palatable grasses and forbs have succeeded in reducing the tall grass prairies to the mixed and shortgrass ranges so widespread in eastern Colorado (Table 3). Prairie remnants are only found today where intensive grazing is no longer practiced.

The second principal cause for the prairie's disappearance has been, and continues to be, Colorado's rapid urbanization. These wonderfully diverse and colorful communities were - unfortunately - most widespread in the Denver metropolitan area. Finding a prairie remnant in this area is like discovering something out of Colorado's pioneering past. Prairie plants "converse only with the dead", Aldo Leopold wrote on his desolate bus ride through the modern Illinois countryside. Has the Colorado prairie a similar destiny - to be forgotten in our willy-nilly haste to prepare the land for more commercial establishments and real estate developments? I found one prairie remnant in a bustling business district in the Boulder city suburbs. The prairie community in full splendor existed on a tract of less than one acre, trisected by a busy, noisy highway on one side, an irrigation ditch which effectively excluded grazing cattle on the second side, and commercial properties replete with filling stations, restaurants, and billboards on the third. This "lot" had indeed been bypassed in the onrush of urban sprawl, and a mini-prairie refuge established by default. Few, however, see behind the billboards into the community of plants and animals beyond. Another prairie in Boulder was not so fortunate. Great yellow monsters belching clouds of smoke and pall and filling the air with angry roar had, in a matter of mere hours, forever relegated a 20-acre prairie to the realm of the dead (Table 4). No one was there to mourn its loss, but the grasshopper sparrow shall never return.

In Colorado we have suddenly arrived at a point in time where laws of diminishing returns and increasing suburban monotony demand drastic reappraisal of prairie worth. This appraisal cannot be entirely based upon economics. Prairies are suddenly very valuable as "people pasture," to again borrow the appropriate phrase from Jim Wilson. In people pasture we harvest not goods and services, but incommensurables. The roads out of Denver carry each weekend, in the words of Lewis Mumford, "a load of desperate people looking for a spot of green or a patch of blue or a pool of quiet -- the mirage of the great metropolitan desert." It's hard to believe that the open spaces of the great Colorado outdoors are filling up so rapidly and with such helter-skelter ugliness. The prairie, however, is restful and beautiful - a metropolitan oasis. And the remaining remnants are well worth searching for and identifying, preserving and including in regional landscape planning, in advance of the bulldozer's hungry maw.

In Colorado we have treated prairies with callous disregard, perhaps out of ignorance. It is not too late, however, to recognize the worth of prairies in the Denver area. They are beautiful and restful natural communities. They contain rare and unusual plants and animals. They provide educational and cultural pursuits. They contribute to landscape diversity and the stimulation that this, in turn, gives to our metnal perceptions. And prairies and prairie tracts are a glorious kind of, simply, open space. With their unique mountain backdrop, the prairies of Colorado are probably unrivalled in their aesthetic value.

Table 1. Geographic elements of the Colorado prairie flora, Boulder and Jefferson Counties. Data based upon 5 relict prairie communities and 2 prairie vegetation associations (Andropogon gerardi/Poa pratensis and Andropogon gerardi/Bouteloua gracilis).

ELEMENT	TYPICAL SPECIES	PERCENT OF PRAIRIE FLORA
Cosmopolitan (Widespread in N.A. or Eurasia)	Prunus virginiana Tragopogon dubius Dactylis glomerata	20
Western	Mahonia repens Linum lewisii Poa secunda	20
Great Plains	Yucca glauca Sphaeralcea coccinea Bouteloua gracilis	32
Cordilleran (Rocky Mt. Montane)	Rubus deliciosus Thermopsis divaricarpa Muhlenbergia montana	15
Eastern U.S.	Ceanothus herbaceus Solidago rigida Andropogon gerardi	7
Southwestern	Ceanothus fendleri Monarda pectinata Lycuris phleoides	6

Table 2. Prairie soil at Mountain Shadows Prairie, Boulder County, Colorado. Parent materials of the upper profile are granitic and sandstone alluvia; lower in the profile, Cretaceous siltstones. Vegetation at the profile site consists of Andropogon gerardi and Poa pratensis with scattered forbs.

HORIZON	DEPTH	DESCRIPTION (FIELD OBSERVATIONS ON JULY 11, 1967)
A1	0-1.5 (dm.)	Very dark gray brown (10YR 3/2 moist or dry) cobbly gravelly sandy loam; very friable; weak fine granular; fibrous roots plentiful; clay 3%; pH 6.4; boundary clear smooth.
A3	1.5-3.5	Dark reddish brown (5YR 3/2 to 3/3 moist) or dark brown (7.5YR 3/2 dry) cobbly gravelly sandly loam; friable; weak fine prismatic; roots plentiful, fibrous roots especially dense around cobble cavities; scattered pockets of reddist brown (5YR 4/4 moist) sand are probably highly weathered sandstone cobble remnants; clay 9%; pH 6.2; boundary clear and smooth.
B1	3.5-5	Yellowish red (5YR 4/6 moist) or dark reddish brown (5YR 3/4 dry) gravelly sandy loam with scattered round cobbles; moderate medium prisms with humus coatings of dark reddish brown (5YR 3/3 moist) on the ped faces; friable when moist, friable-firm when somewhat drier; roots common, usually on ped and stone surfaces; clay 18%; pH 6.5; horizon 0-1.5 dm thick, boundary wavy, abrupt or clear.
B21	5-9	Yellowish red (5YR 4/6 moist) or dark brown (7.5YR 4/4 dry) sandy clay loam; gravels infrequent; strong coarse to very coarse prisms with humus coatings giving a dark reddish brown cast (5YR 3/4 moist) to the ped faces; firm moist and extremely hard when dry; roots common but confined to ped surfaces; clay 30%; pH 6.5; boundary slightly wavy to smooth; abrupt.
IIB22ir	9-11	Yellowish brown (10YR 4/4 moist on ped faces; 2.5Y 5/4 moist in ped interior) or yellowish brown (10YR 5/4 dry) silty clay loam, no gravels or stones; strong coarse to very coarse prisms with humus coatings; friable; roots sparse; clay 36%; pH 6.2; boundary slightly wavy or smooth; gradual.
IIB3	11-14	Olive brown (2.5Y 4/4 moist) or olive yellow (2.5Y 6/6 dry) silt loam; moderate coarse to very coarse prisms with faint humus coatings, the prisms readily breaking into strong medium angular blocks; abundant fine blackish (10YR 3/2) flecks on the angular blocky ped faces; firm; roots sparse; clay 26% at 13-14 dm; pH 6.6; boundary diffuse.
IIC	14-17	Light gray (2.5Y 7/2 dry) silt loam; firm moist and very hard when somewhat drier; strong medium angular blocky breaking into strong fine angular blocky; very local whitish carbonate spots effervescing mildly with HCL; no roots; clay 24%; pH 6.8

Variations

The cobbly layer ranges from 2 to 10 dm in thickness; it may be abrupt to the II material or abrupt to the sandy clay loam of the I layer. The I-II boundary is wavy and independent of the depth within the profile and thickness of the strong prismatic B2. At one profile site the IIB22ir horizon occurred at the 2-5 dm depth. This is probably as shallow within the profile as this horizon occurs in this area. The ir designation implies that the faint reddish coatings on the ped surfaces of of the II material occurs from the illuviation of clay iron derived by the weathering of the I minerals.

Table 3. Influence of grazing on Colorado tall grass prairie. Abundance classes are based upon quadrat studies in the Mountain Shadows Prairie during 1966 and 1967. The abundance classes are as follows: 0, absent or very rare; 1, infrequent and of minor importance; 2, common; 3, very common and subdominant or dominant; 4, extremely abundant and dominant. The comparisons of grazed and ungrazed pastures are based upon fence effect.

SPECIES	ABUNDANCE CLASS	
	Ungrazed	Grazed
Tall grasses		
Andropogon gerardi	3	1
Sorghastrum nutans	2-1	0
Panicum virgatum	2-1	0
Midgrasses		
Stipa comata	1	1
Bouteloua curtipendula	2	2
Poa pratensis	3-4	1
Poa compressa	2	1
Short grasses		
Bouteloua gracilis	2	3
Buchloe dactyloides	2	2
Bouteloua hirsuta	1	1
Aristida longiseta	1	2
Tall forbs		
Tragopogon dubius	2	1
Psoralea tenuiflora	1	2
Solidago rigida	1	0
Intermediate and low forbs		
Artemisia frigida	2	4
Artemisia canadensis	1-2	1
Artemisia ludoviciana	1-2	1-2
Evolvulus nuttallianus	0	1
Low shrubs		
Rosa sp.	1	0-1
Gutierrezia sarothrae	1	1

Table 4. Vegetation of a vanished prairie. During Spring, 1970, the Mountain Shadows Prairie in Boulder County, Colorado (SE1/4 S8 R70W T1S) was wiped out by bulldozers. Vegetation of this approximately 20 acre prairie had been sampled by the canopy coverage method on May 8, June 9, and August 2, 1967.

SPECIES	COV/FREQ/CONST*	SPECIES	COV/FREQ/CONST
Andropogon gerardi	33/64/3	Potentilla fissa	0/3/2
Panicum virgatum	2/5/2	Potentilla hippiana	0/2/
Sorghastrum nutans	4/16/3	Eriogonum alatum	0/2/1
Stipa viridula	9/27/2	Aster porteri	0/4/3
Phleum pratense	0/1/1	Grindelia squarrosa	0/3/2
		Ratibida columnifera	0/1/1
Andropogon scoparius	5/15/3	Taraxacum officinale	0/4/
Sporobolus cryptandrus	1/7/2	Senecio spartoides	0/2/1
Agropyron smithii	1/4/1	Lactuca scariola	0/1/1
Sitanion longifolium	0/5/2	Erigeron flagellaris	0/1/1
Stipa comata	0/6/3	Oxybaphus linearis	0/1/1
Koeleria gracilis	1/17/2	Phacelia heterophylla	0/1/1
Aristida longiseta	0/4/2	Calochortus gunnisonii	0/1/1
Lycuris phleoides	0/1/1	Leucocrinum montanum	0/2/
Bouteloua curtipendula	1/15/3	Apocynum androsaemifolium	0/1/1
Poa pratensis	52/98/3	Heterotheca villosa	0/1/1
Poa compressa	11/40/3	Gaillardia aristata	0/1/1
Eleocharis sp.	2/22/1	Dalea purpurea	0/1/1
Sporobolus heterolepis	p	Liatris punctata	0/1/1
Stipa spartea	p?	Paronychia jamesii	0/1/1
Panicum oligosanthes	0/1/1	Chenopodium sp.	0/4/
Juncus sp.	1/12/2	Artemisia dracunculus	p
		Iris missouriensis	p
Boutelous gracilis	3/35/3	Mertensia lanceolata	p
Bouteloua hirsuta	3/20/2	Lesquerella montana	p
Carex heliophila	5/28/3	Calylophus serrulata	p
Buchloe dactyloides	7/23/2	Thelesperma megapotamicum	p
		Delphinum virens	p
Vulpia octoflora	p	Monarda pectinata	p
Bromus japonicus	0/ /6	Asclepias stenophylla	p
Hordeum pusatillum	0/ /2	Asclepias viridiflorus?	p
		Carduus leiophyllus	p
Artemisia ludoviciana	7/46/3	Solidago missouriensis	p
Aster falcatus	7/33/3	Solidago rigida	p
Tragopogon dubius	6/58/		
Ambrosia artemisiifolia	1/24/3	Gutierrezia sarothrae	0/2/2
Artemisia frigida	1/12/3	Rosa sp.	0/4/1
Artemisia canadensis	1/12/2	Yucca glauca	p
Camelina microcarpa	3/26/	Ceanothus herbaceus	p
Psoralea tenuiflora	3/9/2	Echinocereus viridiflorus	0/2/2
Scorzonera laciniata	1/8/	Opuntia polyacantha	p
Cirsium undulatum	1/4/1		
Penstemon virens	0/6/		
Penstemon secundiflorus	0/2/		
Penstemon virgatus	p		

*Cover and frequency are rounded to the nearest percent; occurrence in 1,2, or all 3 sample areas is indicated under constance. Data are based upon systematic samples of 50 (May and June) or 90 (August) quadrats each 2 x 5 dm and spaced at 1 meter intervals. Presence outside sample quadrats is shown by the p. Plant names follow Weber, W.A., 1967. Rocky Mountain Flora.

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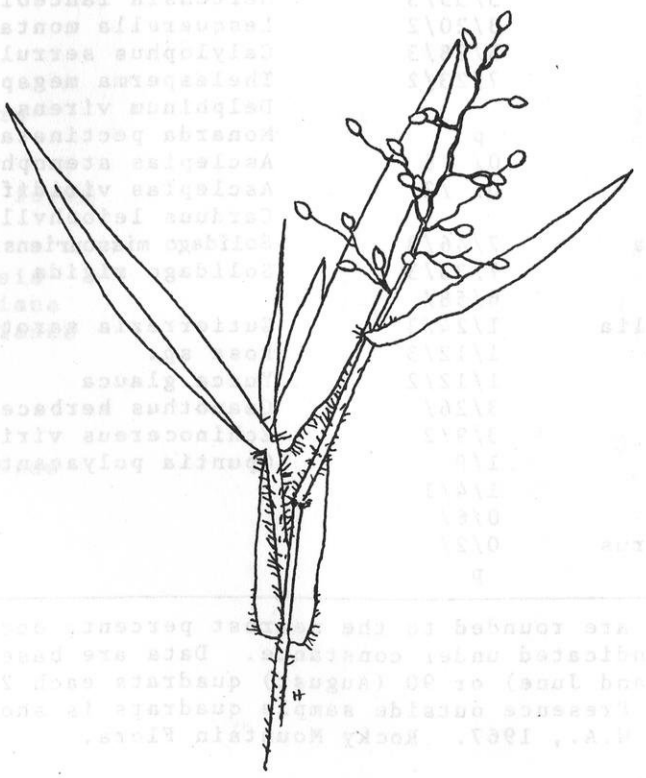


AN INVENTORY OF NATURAL AREAS

By

Paul C. Lemon

Project Leader for I.P.B.
Conservation of Terrestrial Ecosystems
AIBS, 3900 Wisconsin Avenue, Washington, D.C.

Areas set aside for long-term scientific use provide natural outdoor laboratories for analyses of ecosystems of all varieties, complexities, and productivity levels. They may serve as base-line or check areas to measure changes in environmental quality or as control sites in research. Basic data secured for such areas are most valuable in the development of guides to rational husbandry and utilization of natural resources. Such information also enables scientists to determine which ecosystems should remain in a pristine state. Certain preserved areas constitute reservoirs of genetic material vital to medical and agricultural investigations and experiments or provide the last remaining protected habitats of vanishing animal and plant species.

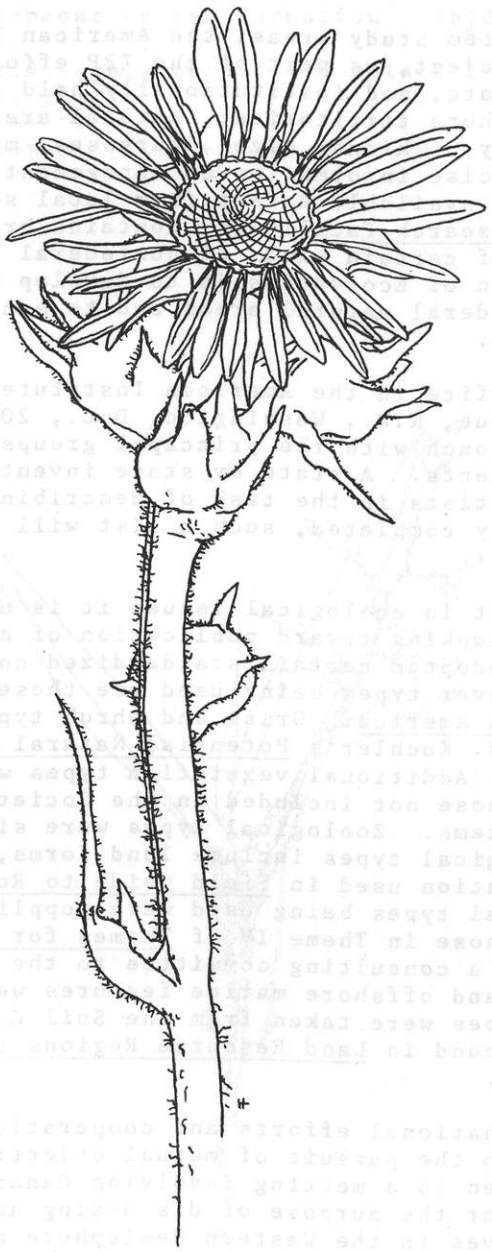
To help preserve ecosystem study areas, the American Institute of Biological Sciences is sponsoring a project, as part of the IBP effort, to compile a comprehensive list of state, private, and institutionally held lands in the continental United States and its off-shore territories. Natural areas under nonfederal ownership include a great variety of kinds, sizes, purposes, management practices, and degrees of protection. Precise information on management practices and kinds of protection is not generally available except from local sources. The A.A.A.S. report, Natural Areas as Research Facilities, contains brief general comments on management and protection of certain kinds of nonfederal areas. An objective of the program for the Conservation of Ecosystems is to develop management and protection practices for various nonfederal natural areas and to encourage satisfactory practices by the various owners.

We have organized an office in the American Institute of Biological Sciences Office (3900 Wisconsin Avenue, N.W., Washington, D.C., 20016). This will make it possible to keep in close touch with the principal groups interested in this phase of the IBP and allied movements. A state by state inventory is being organized with the aid of local scientists in the task of describing and cataloging existing natural areas. When finally completed, such a list will be a standard reference for scientists.

With widespread interest in ecological issues it is urgent that we attempt to coordinate these efforts, looking toward publication of a comprehensive inventory. The Federal Committee has adopted certain standardized nomenclature for classifying these areas. The forest cover types being used are those listed and described in Forest Cover Types of North America. Grass and shrub types, or combinations of these, are according to A.W. Kuchler's Potential Natural Vegetation of The Conterminous United States. Additional vegetation types were developed by the Committee to provide for those not included in the Society of American Foresters booklet or the Kuchler systems. Zoological types were simply 17 major phyla and classes of animals. Geological types include land forms, rocks, and minerals which follow the classification used in Field Guide to Rocks and Minerals. The groupings of paleontological types being used were supplied by the Federal Committee. The aquatic types follow those in Theme IV of Themes for Survey and Evaluation of Natural Areas developed by a consulting committee to the National Park Service. Types for lake shorelines and offshore marine features were also devised by the Committee. Pedological types were taken from the Soil Conservation Service's listing of Great Soil Groups found in Land Resource Regions and Major Land Resource Areas of the United States.

It is hoped that international efforts and cooperation will also move forward. Much planning has gone into the pursuit of mutual objectives in the Americas. Consideration is being given to a meeting involving Canadian, U.S., and Latin American representatives for the purpose of discussing and planning an inventory of existing scientific preserves in the Western Hemisphere and for identification of additional natural areas which should be obtained.

The time is ripe, perhaps over-ripe, for us to make an accounting of our ecological resources. What lands and waters will we need as basic working materials for our research? Myriads of questions are being raised by land owners, land managers, politicinas, and citizens. The ecologist's answers will be as useful as his research permits. It is now important that we examine our research machinery and materials. The public will clamor for the facts and guidance needed for policy formulation in environmental problems. In fact, there is a possible rapid expansion in public and private funding for environmental and biological research. Hence, the publication of a descriptive catalog or inventory of suitable research natural areas becomes urgent business. The excellence of our product (ecological resource management) will be determined by the quality of the machine (research area) and the skill of the operators (working ecologists).



SOME SOIL WATER PHENOMENA AS RELATED TO MANIPULATION OF COVER IN THE CURTIS PRAIRIE, THE UNIVERSITY OF WISCONSIN ARBORETUM: A PRELIMINARY REPORT

By

Francis D. Hole and Kenneth G. Watterston

Professor of Soil Science
University of Wisconsin Extension, Madison, Wis.

Associate Professor of Forest Soils
Stephen F. Austin State University, Nacogdoches, Texas

ABSTRACT

In 1963 and 1964 soil moisture measurements were made at the long term experimental plots that were established in 1956 in the Curtis Prairie of the University of Wisconsin Arboretum. Two Gray-Brown Podzolic soils (Mollic Hapludalfs), somewhat darkened by artificial prairie cover, showed hydrologic differences greater than is suggested by the natural drainage designations of the soils, i.e., well drained and moderately well drained. Manipulation of vegetative cover on plot clusters at the two sites also resulted in different soil moisture regimes. Production of prairie vegetation (dry weight) reached maxima of about 5,000 kg/ha on the well drained soil and 8,000 kg/ha on the moderately well drained one during the growing season of 1964. Least amounts of water were required per kg of vegetative growth on the fired and hence ash-fertilized plot. Water use and loss (combined internal drainage and evapotranspiration) averaged 44 cm at the well drained site and 47 cm at the moderately well drained site, for one meter depth of soil in each. Amounts (cm) of water used and lost averaged for both sites by plot treatment were: mulched soil (vegetation-free), 41.8; bare, 44.5; undisturbed (not fired), 46.7; harvested, 47.3; and fired, 48.1. In the mulched (and weeded) plots precipitation largely drained down through the unsaturated soil profiles in which the moisture content remained close to 30 percent at both sites. Other plots used more moisture during the growing season than was precipitated, and the resulting deficit was made up by infiltration during the non-growing season.

Introduction

An understanding of the natural processes of incroporation of organic matter into soil under prairie vegetation involves a knowledge of the water budget in the ecosystem. The long term experimental plots established in 1956 at two sites in the Curtis Prairie (Cottam and Wilson, 1966) of the University of Wisconsin Arboretum at Madison are so arranged (Figure 1) to permit a study not only of relative importance of above-ground and below-ground plant materials in yielding soil organic matter (Nielsen and Hole, 1963), but also investigations of the relative importance of the terms of the hydrologic equation, namely, precipitation, evapotranspiration, soil water storage and internal drainage. A preliminary study was made in these plots in 1963 and 1964 (Watterston, 1966) by measuring soil moisture content in percent by volume (or cm per meter of soil) to a depth of a meter. This paper reports the data and some interpretations of them.

Soil water depletion is associated with increased densities of vegetation (Metz and Douglas, 1959; de Vries and Wilde, 1962), and removal of vegetation is correlated with increased drainage through the soil and amplified stream flow (Gessel and Cole, 1965; Lambert, 1970; Hewlett and Hibbert, 1961).

The objectives of this study are: (1) to examine the water budget of the experimental plots in the Curtis Prairie, and (2) to relate yields of prairie vegetation to water storage and use.

Table 1. Some Features of The Curtis Prairie Plots (1940 Planting)

FEATURE	PLOTS			
	Bare	Mulched	Harvested	Undisturbed
Number of biopores* in 0-10 cm of soil, expressed as population per m^2	2.5×10^5	5.1×10^5	4.9×10^5	5.8×10^5
Percent biopores* by volume in 0-10 cm of soil (with standard deviations of areas of cross-sections of individual biopores)	0.87 (0.448)	0.98 (0.629)	1.43 (0.417)	1.87 (0.140)
Percent of soil surface occupied by soil crust	98.0	5.0	0.0	0.0
Percent of soil surface covered by moss (*Hypnum sp*) between stems of prairie plants	Tr	0.0	95.0	0.0
Weight of mulch in kg/ha, autumn of 1964	Tr	5624	Tr	5923
Average weekly production** of earthworm casts, June and July, 1965, in g (dry wt.)/m^2	2	275	9	77
Average number of openings to ant nests per plot** (13 m^2), July, August, 1966	17	13	6	3

*Determined by R.E. Puetz by measuring areas of biopores (0.04 to 4 mm in diameter) as observed in freshly broken vertical surfaces of soil.

**Determined by R.E. Puetz.

Table 2. Gross Water Budget[1], 1964 Growing Season, for The Curtis Prairie Plots, University of Wisconsin Arboretum, Madison.

CATEGORY	cm of water in 1 meter soil									
	1940* prairie plots					1950* prairie plots				
	Bare	Mulched	Harvested	Undisturbed	Fired	Bare	Mulched	Harvested	Undisturbed	Fired
Water present, April 25, 1964	29.2	30.9	31.4	30.6	30.8	29.8	31.1	28.7	27.0	29.1
Precipitation during growing season	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6	39.6
Total Water	68.8	70.5	71.0	70.2	70.4	69.4	70.7	68.3	66.6	68.7
Water present November 7, 1964	25.6	28.9	27.1	27.0	22.5	23.6	28.8	17.6	16.5	20.3
Water used or lost** during the growing season	43.2	41.6	43.9	43.2	47.9	45.8	41.9	50.7	50.1	48.4

[1]It is assumed that the surface runoff was negligible on these level plots.

*These portions of the prairie were planted in 1940 and 1950, respectively.
The fired 1940 plot was burned in April, 1963, but not in 1964.
The fired 1950 plot was burned in April, 1964, but not in 1963.

**From one meter depth of soil.

Methods

The content of soil moisture as percent by volume was determined by the neutron scattering method (Wilde et al., 1964) using a Nuclear-Chicago 2800 portable scaler and P-19 depth moisture gauge. Determination of moisture by this method is based on the moderation by hydrogen nuclei of high-energy neutrons. Some of the thermal neutrons of low energy that are scattered by the nuclei are reflected to a detector (McHenry, 1963). A permanent access tube of cold-drawn seamless steel, 4 cm in diameter, 20 gauge, type MT 1015 or 1020 was installed in an auger hole in the center of each of the prairie plots (Figure I). Field measurements were made by lowering the P-19 gauge into the access tube to a desired depth (30 cm, 60 cm, or 90 cm) and intensity of thermal neutron scatter read on the scaler over a period of one minute. Appropriate graphs were used to translate scaler readings into percent moisture by volume. The neutron method supercedes the gypsum and nylon block method used earlier in the University of Wisconsin Arboretum (Link, 1951).

Results and Discussion

Data of 1959-1961 (Nielsen and Hole, 1963) showed that the younger prairie (eastward) established in 1950, on the formerly cultivated moderately well drained forest soil (Zurich silt loam) was more productive of prairie vegetation than the older prairie (1940) on the well drained forest soil (Dodge silt loam), which lay close enough (westward) to the Leopold pines to be shaded somewhat by them early and late in the day. The yields of the harvested, undisturbed and fired plots averaged 7670 kg/ha and 5710 kg/ha (dry weight) on the younger and older prairies, respectively. Corresponding figures for total nitrogen content in 1.3 m depth of soil were 7850 kg/ha and 7200 kg/ha. Yields were increased following spring biennial burning but were depressed in the second growing season. The average yield for both fired plots in years of burning was 8,120 kg/ha as compared with 6,412 kg/ha for harvested and undisturbed plots, and 5,880 kg/ha on fired plots in years of no burning. Yields in 1964 were somewhat less than those reported for 1956-1959 by Nielsen and Hole, presumably because of a lower precipitation in 1964. The unexpected gain during 1956-1959 in total N in soil of the bare plots may be a result of activity of animals (such as defecation and insect nesting) and N-fixing organisms.

Observations in 1956 and 1966 of the surface soil of plots in the older prairie are reported in Table 1 (Puetz and Hole, 1967). The surface soil of the bare plot is crusted, relatively low in content of biopores, nearly free of earthworm activity, but notably affected by ant work. Earthworms and ants are both active in the surface soil of the mulched plot. Moss cover between the stems of prairie plants is the outstanding feature of the harvested plot. The moss cover makes the growing season shorter than on the black spring-fired plot, but not as short as on the undisturbed, mulch-covered plot. The surface soil of the undisturbed plot has the largest population and volume of biopores. It may be expected that infiltration of water into the soil of the bare plot is slower than into the soil at the other plots.

Table 2 reports gross water budgets for the growing season of 1964. The water loss and use includes both free drainage to the water table (which stood at an estimated depth of about 14 meters at the well drained site and 7 meters at the moderately well drained site) and evapotranspiration. Runoff is assumed to be negligible on these level plots. The neutron probe data alone, without tensiometer measurements (Lambert, 1970) do not indicate direction of movement of soil water. Some inferences may be made from data of Table 2 and Figures II through V.

The two columns of figures under the heading of "Mulched" in Table 2 are as similar as duplicates can be, yet they are from soils of different natural drainage conditions. The average use and loss figure of 41.75 cm represents through-drainage of most of the 39.6 cm of precipitation, plus some evaporation. The similarity of the silty sola at the two sites makes this duplication possible.

The other eight water use and loss values (Table 2) exceed 41.75 cm by various amounts of additional water lost by evapotranspiration, and the two soils are shown to be quite different. Amounts (cm) of water used and lost averaged for both sites by other treatments were: bare soil, 44.5; undisturbed (not fired), 46.7; harvested, 47.3; and fired, 48.1. But the harvested and undisturbed plots on the moderately well drained soil used and lost nearly 7 cm more water than did their equivalents on the well drained soil (Figures III, IV). Water use and loss at the bare plots in

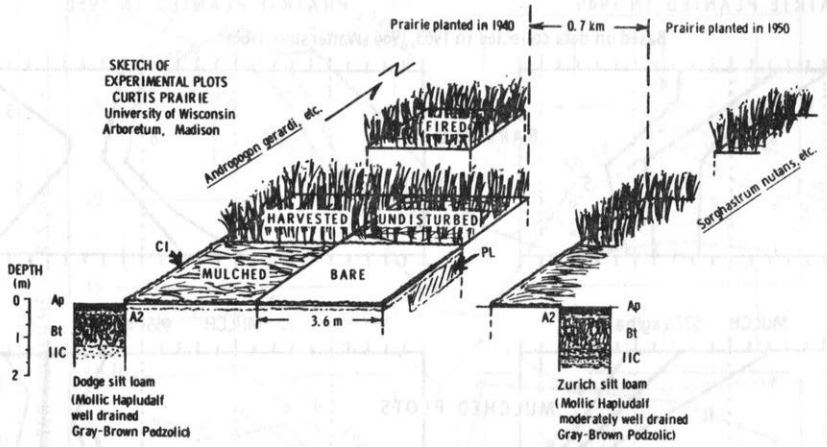


Figure I Diagram showing the nature and arrangement of the two clusters of square experimental plots (each measuring 3.6 m on a side) located, respectively, in the west (left) and east portions of the Curtis Prairie, The University of Wisconsin Arboretum at Madison, since 1956. Galvanized iron metal strips (Cl) 20 cm wide surround the bare and mulched plots and prevent surface runoff. Black silo plastic sheeting (PL), two thicknesses, was installed in 1968 between the weeded plots and adjacent, vegetated ones to a depth of 90 cm. Slope at the sites is less than 2%, but on the bare plots this has been reduced to nearly level by erosion within the low metal fence. (see Map Section for Arboretum locations).

excess of growing season precipitation was 6.2 cm and 3.6 cm (Table 2) and may be attributed to evaporation, which was greater on the more moist soil, possibly because of lateral seepage in the A horizon. The 2 cm soil moisture deficit in both mulched plots may be attributed to evaporation from the mulch and, to a lesser extent, from the mineral soil surface. Soil moisture deficits at the end of the growing season, larger on all but the mulched plots at the moderately drained site than at the well drained site (Figure V), were made up by infiltration during the non-growing season.

The trend of moisture envelopes and the average curves for the 1940 prairie plots in Figure 2 indicates greater depletion of moisture by evapotranspiration from the upper horizons than the lower ones. The silt loam surface soil (A horizon) seems to wet and dry somewhat independently of the silty clay loam B horizon (60 cm depth). The curves for the 1950 prairie plots present a somewhat different story. The near-vertical orientation of the curves for the mulched plot suggests lateral inflow through the A horizon by seepage, even on a 2% slope, over the more clayey B horizon, but this has not been proven. Data presented in Figure II can be better interpreted if we assume that the roots of prairie vegetation go below the one meter depth. This would explain the presence of lush growth of vegetation along the interface between vegetated and nonvegetated plots at the well-drained site and its absence at the moderately well drained site. Availability of ample supplies of soil water below 1 meter at this site accounts for the high productivity of the vegetated plots, and the excessive drying of the A horizon, and the absence of piracy by roots of moisture under the vegetation-free plots.

The early season drop in the moisture curve (top, Figure III for the 30 cm depth of the 1940 plot represents moisture use by rapid new growth on the blackened fired plots. Figure 4 shows a general relationship between amounts of water used and production of dry matter. Lack of a clearer relationship indicates that many factors are operating in ways that have not been sufficiently explored and evaluated in this study.

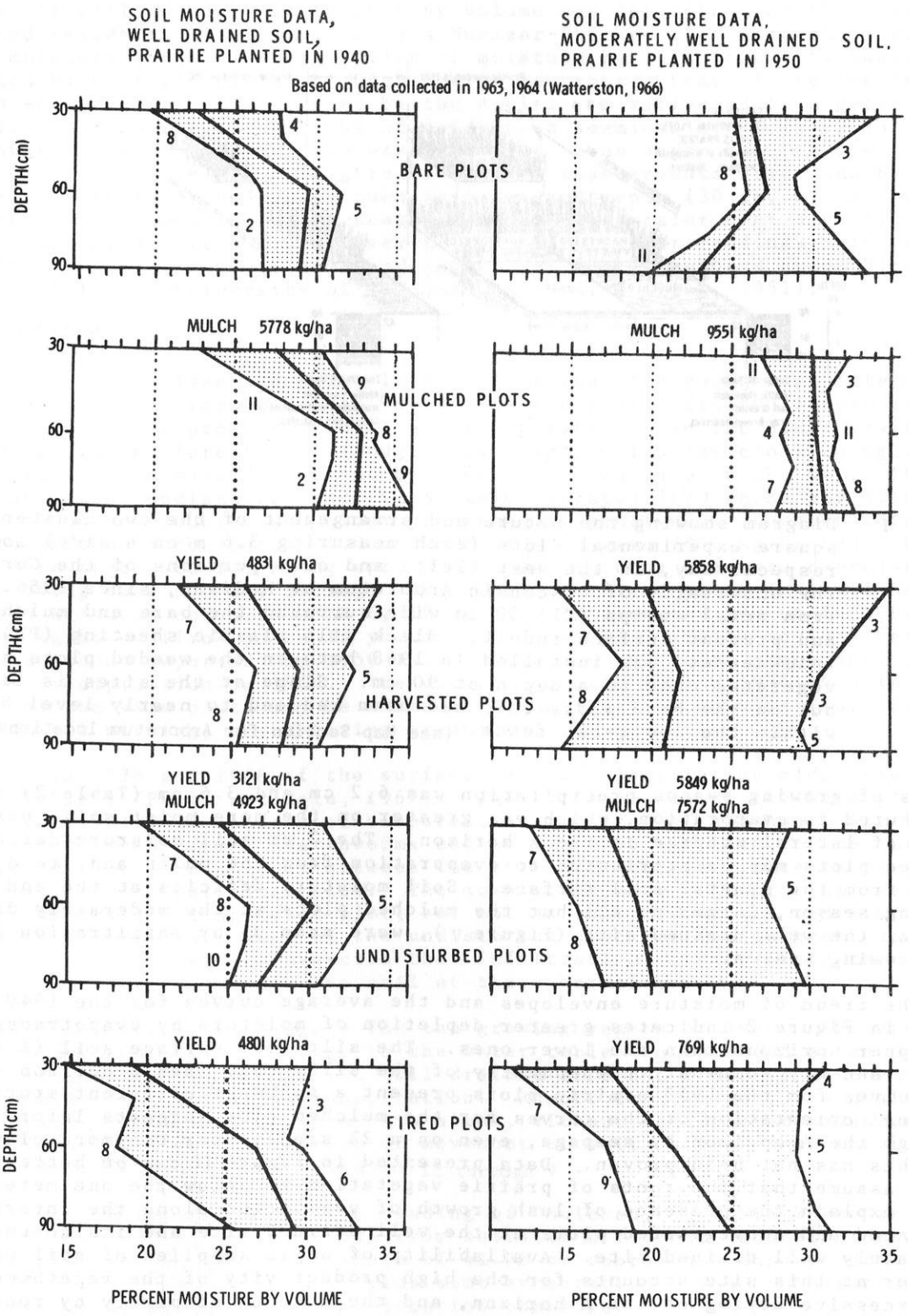


Figure II Envelopes (shaded) of water content in percent by volume (or cm per meter of soil) for 5 experimental plots in each of two portions of the Curtis Prairie, University of Wisconsin Arboretum at Madison. The numerals along the lateral boundaries of the envelopes indicate months when these limits were reached during one or more of two growing seasons (1963, 1964). The central near-vertical line in each envelope represents the average moisture content for the two growing seasons. Dry weights in kg/ha are averages for two growing seasons.

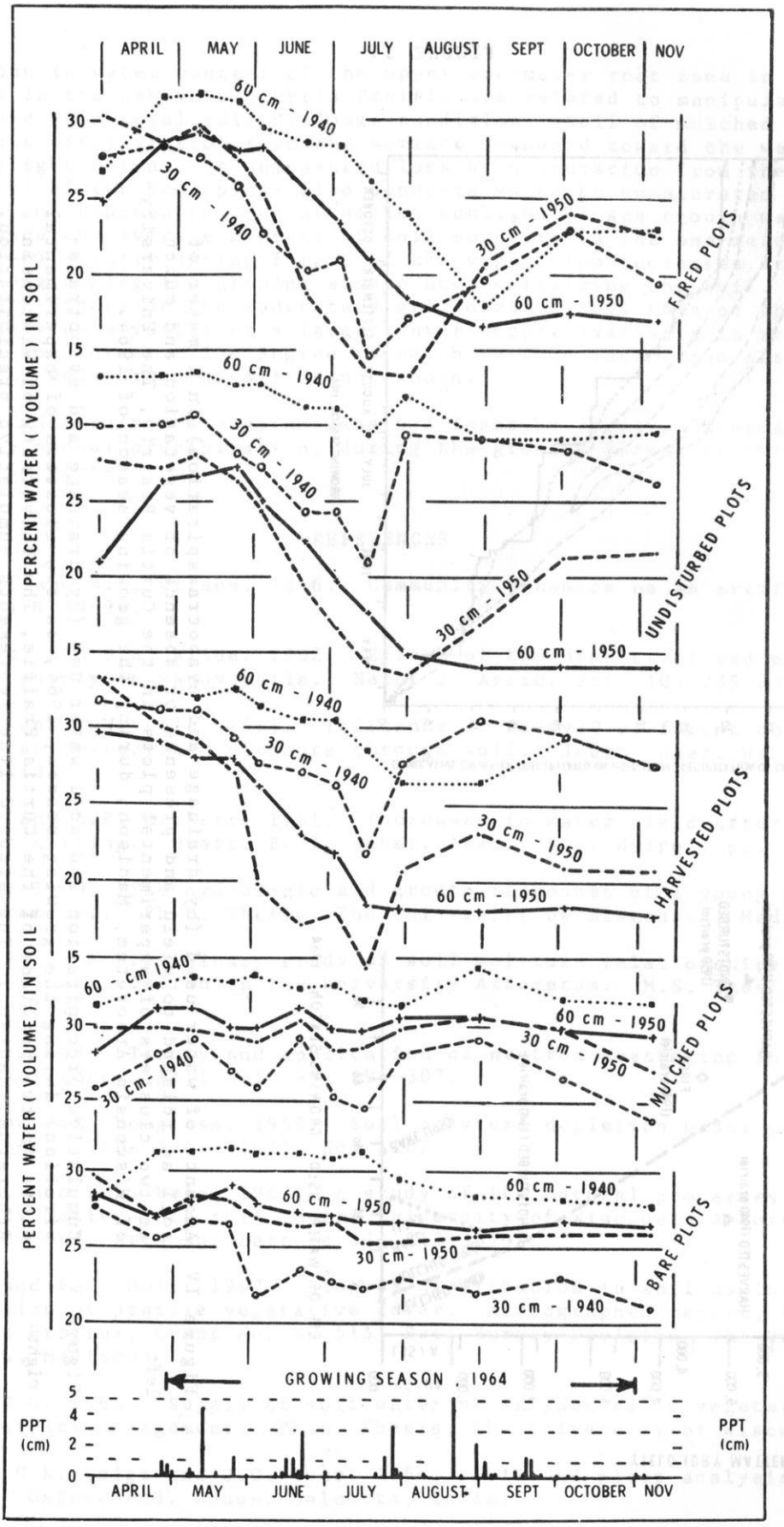
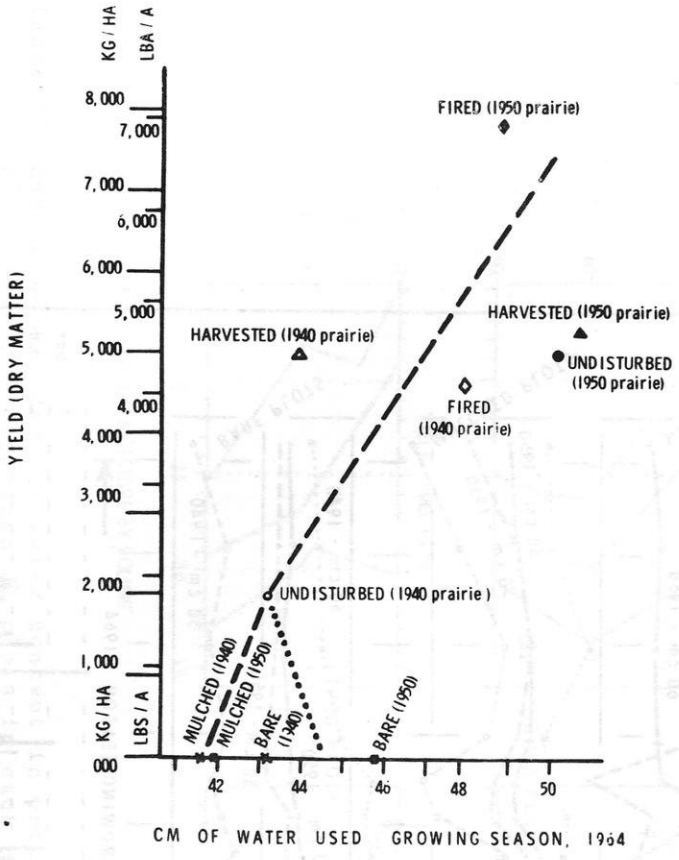


Figure III Precipitation data (below) and average moisture contents through the growing season of 1964 for soil at two depths, 30 cm and 60 cm, in 5 plots in two portions of the Curtis Prairie, the University of Wisconsin Arboretum, Madison.



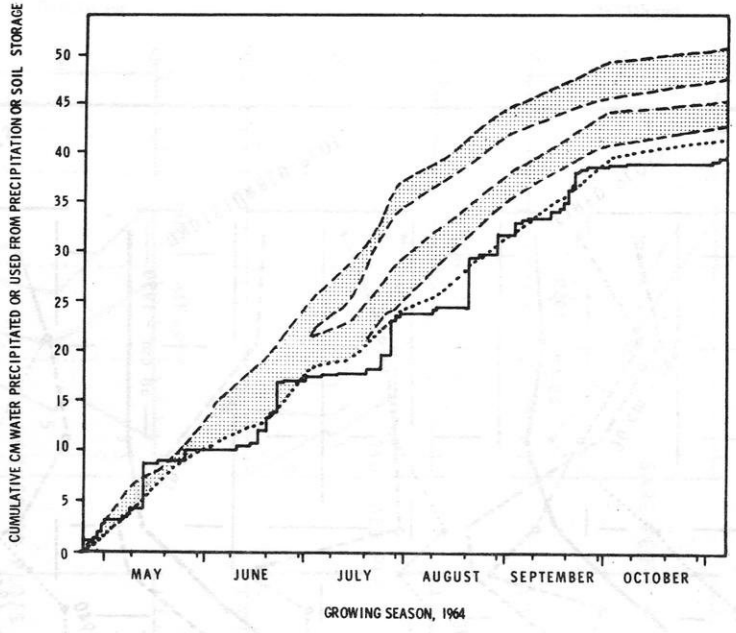


FIGURE IV

Figure IV left — Amounts of water used (by drainage and evapotranspiration) in 1 meter of soil as related to yield and presence or absence of vegetation and mulch at two clusters of experimental plots in the Curtis Prairie, The University of Wisconsin Arboretum, Madison, during the growing season of 1964.

Figure V right — Cumulative precipitation and soil water use (by drainage and evapotranspiration) during the growing season, 1964, on two clusters of experimental plots in two portions of the Curtis Prairie, The University of Wisconsin Arboretum, Madison. The stepped line represents cumulative precipitation. The dotted curve represents cumulative water use of soil at the two mulched barren plots. The band above that includes data for soil at bare plots and the harvested and undisturbed plots of the well drained (1940-prairie) site. The upper-most band includes the harvested, undisturbed and fired plots of the moderately well drained (1950-prairie) site and the fired plot of the well drained site.

Conclusions

Variations in water content of the upper one-meter root zone in soil at experimental plots in the Arboretum Curtis Prairie are related to manipulation of vegetative cover and to natural soil drainage condition. Soil of mulched (and weeded) plots conducts precipitation from the surface downward toward the water table, and there is a slight but as yet unmeasured loss by evaporation from the mulch and soil surface. Soil of the bare plots also conducts water by unsaturated flow downward, but, crusted and exposed to heat of direct sunlight, loses enough water by evaporation to reduce the average content of soil moisture in the one-meter root zone by about 4 cm (4%). Early spring firing of the vegetation increases dry weight production by lengthening the growing season and fertilizing the soil. Yields of vegetation are higher on the moderately well drained soil than on the well drained one, presumably as a result of a larger water supply available in the 2 meter profile to plants in the former. The degree to which surface runoff and seepage may occur in the moderately well drained soil is not known.

At most, the prairie ecosystem uses and loses by internal drainage about two-thirds of the annual precipitation, during the growing season at the sites of the Curtis Prairie plots.

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COLONY SIZE AND LONGEVITY AS INDICATED BY MOUNDS OF A PRAIRIE ANT

By

Russel O. Wagner and John T. Medler

Department of Biology, Wisconsin State University--Platteville

And

On Leave, Department of Entomology, University of Wisconsin,
Madison, Wisconsin

ABSTRACT

Over a period of eleven growing seasons (1956-1962), records were kept of changes in numbers and sizes of mounds of the ant Formica cinerea in a prairie remnant along a railroad right-of-way. Height, length (in relation to the transects) and cross dimensions of the mounds were taken in four transects 150 x 1 meter in an attempt to learn something of the growth pattern of the colonies present and of the colony longevity. All colonies included were examined at least once annually between 1956 and 1962 inclusively and again in 1966. Of 58 Formica cinerea colonies present in 1956, 40 remained after 10 growing seasons, and 16 were lost by 1962. In addition, 38 new colonies appeared between 1957 and 1966, of which 27 remained in 1966. Mound measurements suggest that changes in size correlate with the general condition of the colony - growth to a maximum size, some "settling in old age", and finally the compaction of the soil and vegetation overgrowth following colony demise. The data are inadequate as yet to estimate the probable average and maximum colony age. All eleven colonies lost perished by the end of their fifth growing season. Not included here were over 70 colonies, possibly small groups of ants tending aphids, which lasted only one or a fraction of a growing season.

A prairie remnant containing over 120 native prairie species exists along a railroad right-of-way on the Grant-LaFayette County line in southwest Wisconsin. Of Curtis' (1955) 50 prairie indicator species, 10 in each of five groups of wet to dry prairie types, 31 species are present in this remnant. Included are all ten from the mesic group with decreasing numbers toward the wet and dry types. An interesting animal feature of this remnant is the presence of a large number of colonies of the ant Formica cinerea Mayr. Sample plots indicate that these mounds are randomly spaced and average about 400 per acre.

A life history and population study of this ant has been under way since 1956 by the co-authors with financial aid from the Wisconsin Alumni Research Foundation. One aspect of this study has involved periodic examination of four transects, each 150 meters long by one meter wide. Each meter has been examined for the presence and size of any mound which lay within or touched the margins of the transect. Horizontal measurements have been taken of each mound parallel to and across the transect. These and mound height were measured to the nearest half inch. Early observations led to the assumption that the size and condition of a mound could serve as an indication of the size and vigor of the colony producing it. We hoped to learn from these observations something of the growth pattern of these colonies as well as their longevity.

Data obtained show these mounds to increase in size over a period of years but to temporarily decrease upon soil compaction during the inactive part of each season. Ultimately they decrease with the aging of the colony, and then gradually disappear with its demise. The pattern resembles that of the life of a human being. For example, a mound first found in July, 1957 measured 2 x 3 x 1 1/2 inches high. Succeeding changes found were:

August 1957 -- 6 x 7 x 2"
June 1958 -- 5 x 6 x 2 1/2"
August 1958 -- 8 x 10 x 6"
August 1959 -- 8 x 9 x 8"
September 1960 -- 12 x 144 x 9"
September 1961 -- 12 x 15 x 9"
September 1962 -- 13 x 15 x 12 1/2"
September 1966 -- 18 x 18 x 10"

Another colony in August 1957 measured 20 x 24 x 7 1/2". In 1959 it was found to be 22 x 25 x 9" but required disturbance of the mound in order to detect evidence that the colony was still alive. In September 1966, the mound remains was obviously compacted and the colony definitely dead.

Of the original 58 mounds (and colonies) recorded in the 600 meters of transect in 1956, forty were still alive in 1966. In the six years including 1957-1962, the number dying anually were one, six, five, three, one, and zero respectively. Two more died out between 1962 and 1966. Also during that ten year period, 38 new small mounds appeared of which 27 remained active in September 1966. Of the 11 that perished, one disappeared after only one year, four after two years, three after three years, one the fourth, and two after five years. The early life of an ant colony experiences its difficulties as do individuals of a species.

Excluded from the figures presented are 73 mounds that were found early each growing season, i.e., June, before the year's crop of reproductives appeared. These mounds were always small, e.g., 1 x 2 x 3", and always disappeared later in the summer. Excavations of a few showed these to be composed of a few dozen workers and invariably some root aphids. The mounds apparently served as "barns" for the ants' "cows".

It is early to make any positive statements regarding the maximum age of a colony of F. cinerea. Many of the forty colonies active after 10 years of observations were represented by large mounds when first recorded. Dreyer (1942) in a study of the ant Formica ulkii in Illinois estimated the average age of those colonies to be about 15.2 years and estimated a maximum age of 25 years. Guesses could be made for F. cinerea on the basis of changes in mound size. On this basis, Dreyer's values appear reasonable, possibly minimal, for this species on this prairie remnant.

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DISTRIBUTION AND PHENOLOGY OF A PRAIRIE SOIL ARTHROPOD POPULATION

By

John Lussenhop

Department of Zoology
University of Wisconsin, Madison

ABSTRACT

Three monthly collections of forty cores each from the Curtis Prairie, University of Wisconsin Arboretum, Madison, Wisconsin, illustrate population change and seasonal movement of arthropods within the top centimeters of prairie soil. One hundred and ten species of microarthropods can be quantitatively extracted with a high gradient apparatus. The fauna may be divided physiognomically into a group of relatively large, pigmented, well-sclerotized herbivores and carnivores living close to the soil surface, and smaller, less pigmented and sclerotized forms living deeper in the soil. Seasonal movement between plants and soil is suggested by absence of the species of Tetranychidae (Acarina) and Pseudococcidae (Homoptera) in the soil at certain times of the year.

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Introduction

Grassland soil arthropods have been studied in both North American prairies and European grasslands. Pasture, old-field, and fen soil arthropod studies augment the limited picture offered by prairie studies. This review of grassland soil arthropod studies relates results of previous studies to a study of soil arthropods in the Curtis Prairie of the University of Wisconsin Arboretum, Madison, Wisconsin.

Methods

Forty soil cores each were collected in April, August, and November, 1969. In each month four cores were randomly sampled from each of ten 100 m^2 blocks in the west end of the Curtis Prairie (Figure III). The blocks were arranged so that centers of blocks in the first column were 20 m from the Leopold Pines, and the centers of blocks in the second column were 60 m from the pines. (See general U.W. Arboretum map, elsewhere in these proceedings, and Figure I in Riechert paper following.)

The 9 cm deep cores have a surface area of 19.17 cm^2; efficiency of this size of core relative to larger cores has been shown for Curtis Prairie populations (Lussenhop, 1971 a). Efficiency of extraction from the soil has been estimated for the Curtis Prairie collections, and then applied as correction factors to numbers of organisms actually extracted from soil (Lussenhop, 1971 b).

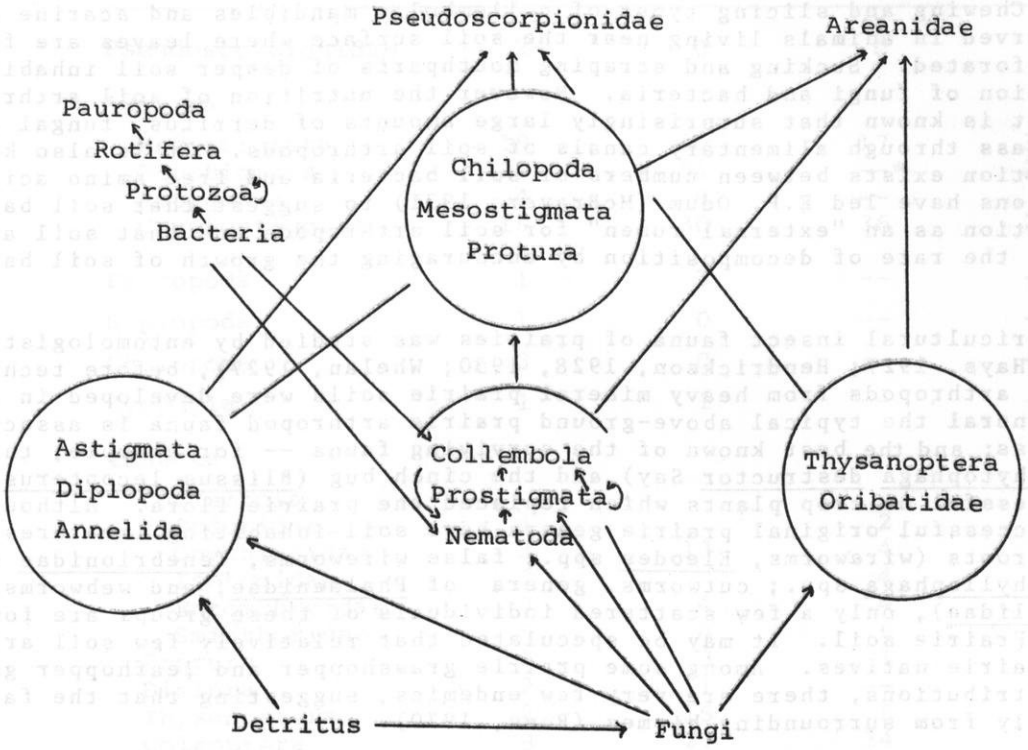
Briefly, the microarthropods were obtained with a steel corer using cardboard orange juice cans as core liners, and extracted from the soil by relying on their own movements to avoid desiccation. The high gradient extractor heats the soil slowly along a uniform front, causing microarthropods to move through, and finally out of, drying soil. A gradient of about 10° C is maintained between the top and bottom of the 3 cm core sections. Foam rubber holds a soil core section and nylon netting in place over a crystallizing dish of picric acid. A large pad of foam rubber holds 64 soil cores, constantly illuminated and gradually heated with bulbs placed one meter above the soil cores; a 100 watt bulb and a 250 watt, infrared bulb are connected to a rheostat. Below the foam rubber pad, crystallizing dishes sit on a screen in a cold water bath. Throughout the 7 to 10 days of extraction, the water bath temperature is lowered, and heat from the infrared bulb is increased.

Results and Discussion

Soil arthropods are part of a large biota composed of bacteria, fungi, algae, and members of five animal phyla. The numbers of these groups represented in a single soil plot are highly variable, and due to the different tehcniques necessary to extract or culture groups of the soil biota, there are no studies of the total biota in any one site. The contribution of each taxonomic group to the total soil biomass is not known. Also, interactions among the soil biota are poorly documented; Figure I. is a general summary.

FIGURE I

A Generalized Soil Arthropod Foodweb



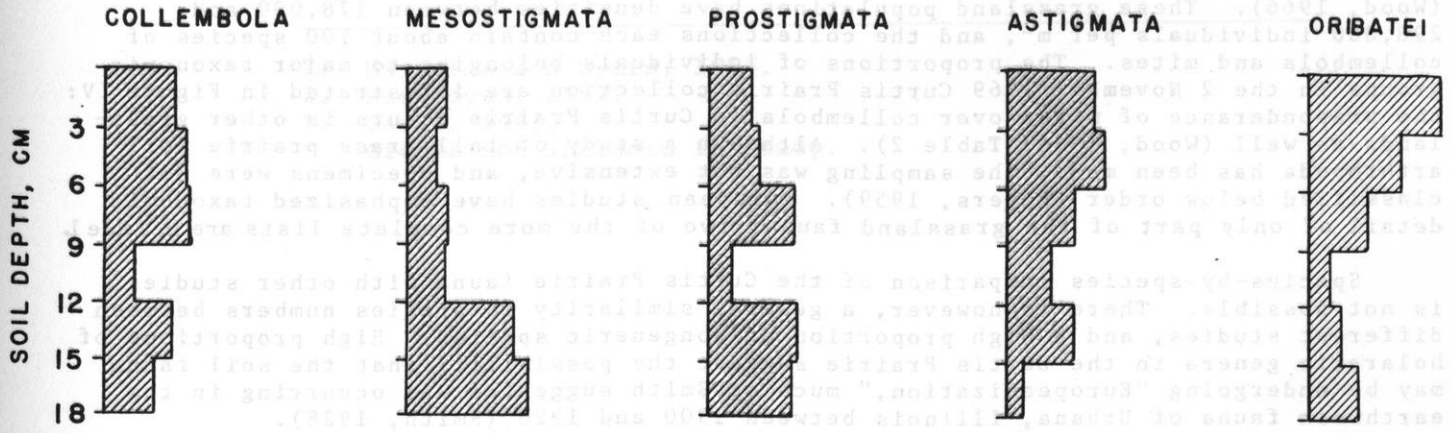


FIGURE II

Vertical Distribution of Soil Arthropod Groups in Curtis Prairie
3 November 1970, in Terms of Percent of Individual Numbers

The soil arthropod fauna of the Curtis Prairie is composed of seven arthropod classes and about 130 species. The fauna is distinct from the soil surface arthropod fauna in that all nourishment is derived ither directly or indirectly from soil detritus and fungi. The vertical distribution of the Curtis Prairie fauna is shown in Figure II.

Feeding habits of many soil arthropods are implied by the structure of their mouth parts. Chewing and slicing types of collembolan mandibles and acarine chelicerae are observed in animals living near the soil surface where leaves are fenistrated and perforated. Sucking and scraping mouthparts of deeper soil inhabitants suggest ingestion of fungi and bacteria. However the nutrition of soil arthropods is unknown. It is known that surprisingly large amounts of detritus, fungal spores and bacteria pass through alimentary canals of soil arthropods. It is also known that a correlation exists between numbers of soil bacteria and free amino acids. Such observations have led E.P. Odum (McBrayer, 1971) to suggest that soil bacteria and fungi function as an "external rumen" for soil arthropods and that soil arthropods influence the rate of decomposition by encouraging the growth of soil bacteria and fungi.

The preagricultural insect fauna of prairies was studied by entomologists (Adams, 1955; Hays, 1927; Hendrickson, 1928, 1930; Whelan, 1927), before techniques for extracting arthropods from heavy mineral prairie soils were developed in the 1940's. In general the typical above-ground prairie arthropod fauna is associated with bunch grass; and the best known of the surviving fauna -- for example, the Hessian fly (Phytophaga destructor Say) and the cinch bug (Blissus lecopterus Say) -- became successful on crop plants which replaced the prairie flora. Although some of the successful original prairie genera have soil-inhabiting immatures which feed on plant roots (wireworms, Eleodes spp.; false wireworms, Tenebrionidae spp.; May beetles, Phyllophaga spp.; cutworms, genera of Phalaenidae; and webworms, genera of Pyralidae), only a few scattered individuals of these groups are found in the Curtis Prairie soil. It may be speculated that relatively few soil arthropod species are prairie natives. Among some prairie grasshopper and leafhopper groups with known distributions, there are very few endemics, suggesting that the fauna is drawn largely from surrounding biomes (Ross, 1970).

In general, temperate grasslands have fewer individuals and species of soil arthropods than mor or mull forest soils, but many more than tropical grasslands (Raw, 1967). Th Collembola and Acarina of European pastures, Sesleria, Festuca-Agrostis, and Nardus grasslands, as well as a Molinia fen, have been studied (Wood, 1966). These grassland populations have densities between 178,000 and 298,000 individuals per m^2, and the collections each contain about 100 species of collembola and mites. The proportions of individuals belonging to major taxonomic groups in the 2 November 1969 Curtis Prairie collection are illustrated in Figure IV: the preponderance of mites over collembola in Curtis Prairie occurs in other grasslands as well (Wood, 1966; Table 2). Although a study of tall grass prairie soil arthropods has been made, the sampling was not extensive, and specimens were not classified below order (Rogers, 1959). European studies have emphasized taxonomic detail of only part of the grassland fauna; two of the more complete lists are in Table 1.

Species-by-species comparison of the Curtis Prairie fauna with other studies is not possible. There is, however, a general similarity in species numbers between different studies, and a high proportion of congeneric species. High proportions of holarctic genera in the Curtis Prairie suggest the possibility that the soil fauna may be undergoing "Europeanization," much as Smith suggested was occurring in the earthworm fauna of Urbana, Illinois between 1900 and 1926 (Smith, 1928).

Acarina and Collembola dominate the soil fauna in both species number and number of individuals (Figure IV; Table 2). Acarina and Collembola are small forms. Larger forms are less common, although there are more Protura and Pseudoscorpionidae individuals in the Curtis Prairie than in other grasslands (Table 2). Prostigmatid mites, a diverse group of saprovores and carnivores, are richest in species and individuals. In Curtis Prairie, fungivorous Oribatid mite species are about as well represented as carnivorous Mesostigmatid species, but much more numerous as individuals. Astigmatid mites are represented by only a few species in the Curtis Prairie, although individuals can be quite abundant in some soil cores. This is characteristic for grasslands in general (Davis, 1963; Sheals, 1957) where these saprovorous mites do not seem able to compete effectively with the fauna of environmentally diverse soil.

Table 1: Soil Arthropod Species Numbers in Prairie and Grassland Faunas

Group	Curtis Prairie Wisconsin	Old field Michigan[1]	tussocks England[2]	grassland England[3]
Pseudoscorpionidae	2	0	0	0
Acarina				
Mesostigmata	18	10	17	37
Prostigmata	21	51	--*	20
Astigmata	4	4	--	4
Cryptostigmata	19	30	36	20
Pauropoda	1	3	--	--
Diplopoda	1	0	--	--
Chilopoda	3	0	--	--
Symphyla	1	1	--	--
Insecta				
Collembola				
Poduridae	4		2	3
Onychiuridae	3	13	4	7
Isotomidae	7		4	8
Entomobryidae	7	4	4	5
Sminthuridae	5	4	6	9
Protura	2	3	1	--
Diplura	2	1	--	--
Thysanoptera	2	15	5	--
Coleoptera	8	27	34	--
Lepidoptera	3	5	1	--
Diptera	10	13	15	--
Hemiptera	0	4	7	--
Homoptera	3	11	2	--

1. Hairston and Byers, 1954.
2. Macfadyen, 1952.
3. Davis, 1963.
* Groups not included in study.

Table 2: Total Number of Arthropod Individuals in Curtis Prairie* and Spinney Pasture, Cambridge, England*

Group	Numbers per Square Meter			
	April* 1969	May* 1969	November* 1969	November** 1943
Pseudoscorpionidae	136	532	117	56
Acarina	50,373	72,093	84,199	164,363
Mesostigmata	2,530	9,138	2,813	
Prostigmata	20,744	19,016	55,989	
Astigmata	1,942	2,388	5,850	
Oribatei	25,157	41,551	19,547	
Pauropoda	280	170	77	629
Diplopoda	15	46	0	401
Chilopoda	0	612	698	628
Symphyla	15	542	31	3,867
Insecta				
Collembola	4,443	41,981	25,055	61,269
Protura	775	4,034	3,412	1,363
Diplura	0	77	170	1,363
Thysanoptera	41	288	181	1,129
Coleoptera	329	739	259	4,397
Lepidoptera	0	191	0	62
Diptera	424	355	286	672
Homoptera	0	232	1,478	17,724
Hymenoptera	0	177	68	191
	57,255	122,069	155,941	263,658

* Corrected for extraction efficiency

** Salt et al., 1948. Extraction was by flotation in magnesium sulfate solution and sieving through 0.2 mm mesh (samples 1-11) and 0.1 mm mesh (samples 12-20). Core depth: 30.5 cm.

Terminology

Useful terminology distinguishing litter and superficial soil inhabitants from those living deeper in the soil has been generalized from Gisin's use of hemiedaphic and euedaphic for Collembola (Gisin, 1943). Hemiedaphic and euedaphic will be used for soil arthropods in general, to separate pigmented soil arthropods with eyes, long antennae and legs from unpigmented eyeless forms with shortened antennae and legs.

Due to their feeding habits, soil arthropods occur in small, dense clusters in the soil. Existence of such aggregations is inferred from occasional occurrence of many individuals of a species in one soil core. Two measures of aggregation are useful in describing aggregations of single species, as well as aggregations of all the species in a soil core.

Aggregation of individual species or their stadia can be described with the statistic, mean crowding,

$$(\overset{*}{x} = \bar{x} + s^2/\bar{x} - 1)$$

which equals the mean ($\bar{x}$) when the distribution is random and is greater than the mean for aggregated species. Mean crowding is more independent of the total numbers of individuals in the collection than is the often used measure, $s^2/\bar{x}$.

Aggregation of all the species and their stadia in a soil core collection is also a useful measure because it is analogous to totaling $\overset{*}{x}$'s over all species and their stadia in a collection. This measure (relative diversity), R.D., is an estimate of the degree to which individuals are not equally distributed among all of the species and their stadia in a collection. R.D. is the ratio of observed to expected diversity using the Brillouin equation to measure diversity (Brillouin, 1962). The actual value calcualted is,

$$s(N/s)!/\prod_{i=1}^{s} N_i!$$

for s species and $N_1 + N_2 + N_s = N$ individuals.

As an example, if in 5 collections two species are represented by the same number of individuals but with different frequencies,

Species 1	5,0,0,5,0	$\overset{*}{x} = 0.383$
Species 2	2,1,2,3,2	$\overset{*}{x} = 0.780$

individuals in the less frequent species will be less crowded.

Turning from individuals to collections, 2 collections which contain the same number of individuals and species will have the same maximum possible diversity, but to the extent that their observed diversity is different, their relative diversity is distinct also.

Collection 1 5,0,0,5,0

Max. Div. = 0.808 Obs. Div. = 0.383 R.D. = 0.474

Collection 2 2,2,2,2,2

Max. Div. = 0.808 Obs. Div. = 0.808 R.D. = 1.000

Seasonal Change in the Curtis Prairie Soil Arthropod Population

A picture of soil arthropod density, aggregation, and distribution during a year between biennial burning, can be sketched using primarily collections of April, August, and November, 1969. Arrangement of the 10 sampling blocks into 5 rows and 2 columns paralleling the Leopold Pines, allows distinction of row and column effects in distribution of soil arthropods within the 6,500 m^2 study area (Figure III).

The total number of individuals doubled between April and November, 1969, while the proportion of immatures rose from 10 to 19%. During the same period, numbers of stadia and individuals in each soil core became increasingly variable (Table 3). Most of this variability is between blocks rather than rows or columns of blocks, until November when significantly more stadia and individuals are found in the prairie center.

FIGURE III

Sampling Blocks in the Curtis Prairie. Blocks are 100 m^2 (See Figure I in paper by Riechert, following, for locations of Numbers 1 and 2 for correspondence of site and see Map Section for general Arboretum locations.)

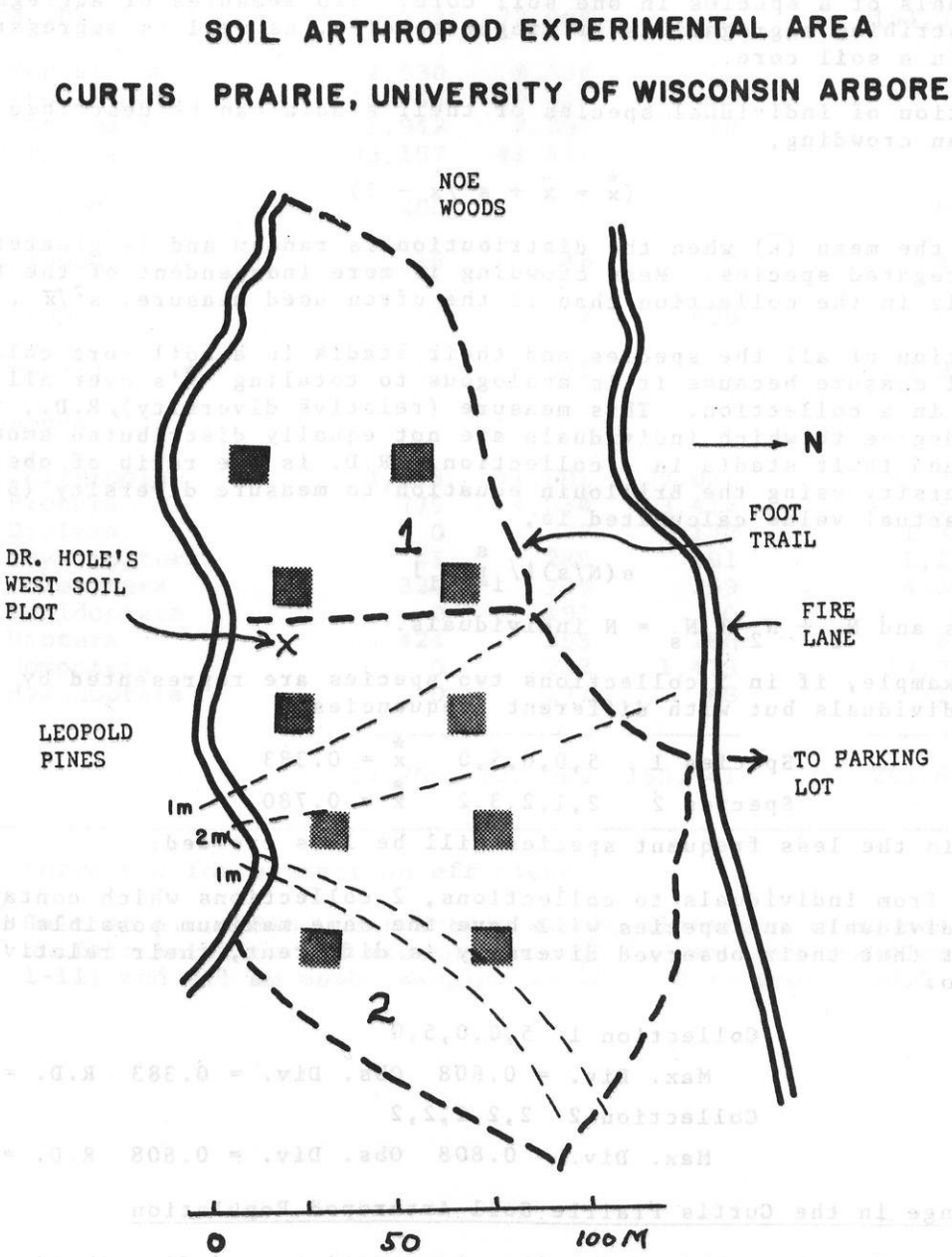


Table 3: Analysis of Variance for Number of Stadia, Number of Individuals, and H_{obs}/H_{max} in Curtis Prairie Soil Arthropod Collections, 1969

		Mean Squares		
		Stadia		
Source of Variation	d.f.	April	August	November
Rows	4	150.9*	100.2	243.2**
Column	1	122.5	0.4	396.9**
Interaction	4	242.4*	259.3*	388.6**
Error	30	41.7	56.2	23.7

		Mean Squares		
		Individuals		
Source of Variation	d.f.	April	August	November
Rows	4	5405.2	1335.7	13527.1
Column	1	550.0	28.9	56625.6*
Interaction	4	11068.3	2648.7	49153.5
Error	30	3392.9	949.5	7725.7

		Mean Squares		
		H_{obs}/H_{max}		
Source of Variation	d.f.	April	August	November
Rows	4	.0017	.0006	.0069
Column	1	.0069	.0037	.0167*
Interaction	4	.0080	.0023	.0131
Error	30	.0070	.0006	.0045

* Significant at the 25% level.

** Significant at the 10% level.

Table 4: Total Variance and Standard Error of Variances for Soil Arthropod Stadia Collected in November, 1970

Group	S^2	Standard Error of Variance
Mesostigmata	52.2	140.2
Collembola	188.2	619.2
Oribatei	547.0	1909.0
Prostigmata	689.6	1839.3
Protura	991.9	2010.6
Astigmata	2778.8	4640.6

Aggregation, as measured for all species in a core collection by R.D., is lowest in August and shows greater variation between columns than between blocks. In November, mean squares for individuals, species, and R.D. are significant for columns, indicating that as the number of stadia and individuals increase away from the pines, patchiness increases also (Table 3).

Species and stadia represented in any particular soil core collection are quite variable except for five species present in over 80% of the collections. These species are all euedaphic: Rhodocarus sp., Hypochthonius sp. 1, Suctobelba sp. 1, Tullbergia granulata, and Eosentemon sp. In general, other euedaphic species are less frequent but relatively consistent in occurrence. The more superficial hemidaphic species tend to be variable in numbers and less consistent in occurrence.

Whole families and orders vary greatly in representation in soil cores. In general, variance for a group and the standard error of variances for the stadia in the group increase in the same order (Table 4). Taxa with the most aggregated species are composed largely of fungivores. Only in the Prostigmata, a heterogenous group containing predators, fungivores, microphytes, and herbivores, is the standard error of individual variances out of sequence with total variance.

The patchy individual distributions responsible for such variability can be described with the statistic mean crowding ($\overset{*}{x}$). In general, predaceous species have relatively low $\overset{*}{x}$, up to 5 times the mean density the population would have if individuals were distributed randomly. One predaceous prostigmatid, Alicorhagia sp., is distributed regularly. Greatest values of $\overset{*}{x}$ are generally observed for saprovores and fungivores (Peymotidae, Tarsonemidae, Scuticaridae, Oribatei and Collembola).

Distributional pattern in some species can be distinguished within the study area. For example, half of the hemiedaphic Collembola which reproduce in the summer are more numerous as individuals in the blocks closest to the Leopold Pines.* This correlation is observed among predominantly scaled Entomobryidae (Orchesella ainsliei, Pseudosinella sp.), Isotomidae (Folsomia fimetaria), and Sminthuridae (Arrhopalites sp.). However the row (east-west) effect is also important in distribution of two of these species: Orchesella ainsliei and Pseodosinella sp. were collected only in blocks in the drier, west end of the study area. One euedaphic species, Tullbergia granulata, was found in greater numbers near the pines. Of the collembola which reproduce in fall or winter, almost all are more numerous in the column closest to the pines (Brachystomella sp., Folsomoides sp., Folsomia elongata, Lepidocyrtus cyaneus, and Neelus sp.).

Oribatid distribution is less strongly affected by the pines even though most are found close to the soil surface. The only euedaphic species are Hypochthonius sp., Suctobelba spp., and one of the two species of Eobrachychthonius. One hemiedaphic species (Epilohmannia sp.) and an euedaphic species (Hypochthonius sp. 1) are most numerous near the pines. Only Caraboides sp. (limited to the east row) and Masthermannia sp. (limited to west rows) were not found in all blocks. Immatures of three species were not found; in previous oribatid studies when larvae were not extracted from soil, they were found burrowing in grass culms (Riha, 1951). It is possible that immature Cultoribatula sp. and Suctobelba spp. were not found for a similar reason. The greatest number of oribatids reproduce in the fall, and larvae and protonymphs of 15 species were found then. However, Epilohmannia sp. and Neoribates sp. reproduce in the spring.

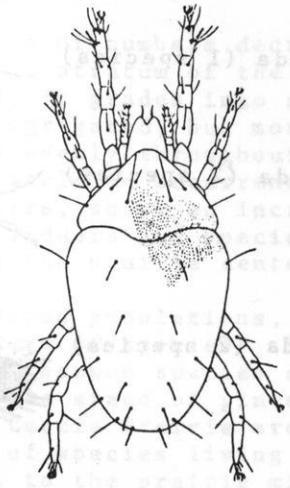
Five prostigmatid species are more numerous close to the pines. This is true only in spring for Erynetid sp. 1 and only in fall for Tydeus sp.. Scuticarids and Tarsonemids are not numerous in spring; other prostigmatid groups do not show pronounced seasonal maxima, or preferences within the study area.

*Ed. Note: The dense 36-year-old white and red pines, on a slight north-facing slope, no doubt have a considerable effect on soil and air temperatures and moisture content, and possibly soil acidity. See Selleck, G.W. and K Shuppert, 1957. Some aspects of microclimate in a pine forest and adjacent prairie. Ecology 38(4): 650-653; and Rees, Colin, 1967. Effects of Arboretum pines on soil pH. Arb. News 16:34.

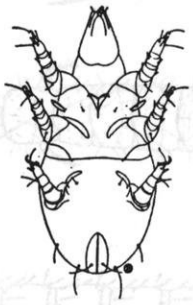
Pictorial Synopsis -- Arboretum

I. Acarina

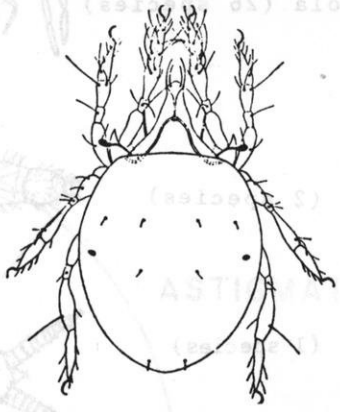
Mesostigmata (12 species)



Prostigmata (19 species)

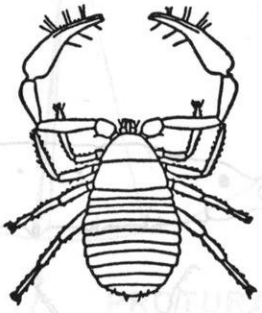


Astigmata (4 species)



Cryptostigmata (20 species)

II. Pseudoscorpionidea (2 species)

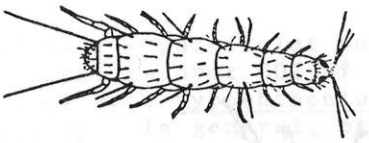


One mesostigmatic mite is most numerous in the blocks near the pines (Hoploseius sp.), and one species is most common in the center of the field (Dermanyssis sp.) Most mesostigmatids are found close to the soil surface except for Rhodocarus sp. 1, a member of a well-known genus of deep soil predators (Sheals, 1957). In Curtis Prairie, over half of the specimens of this species are found below 9 cm.

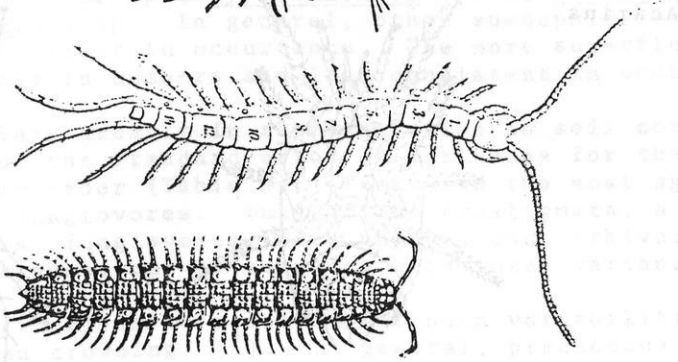
The Curtis Prairie proturan population is similar to that of the Rothamsted Park Grass plots in that two species are present in unequal numbers, and the group is unusually abundant in comparison to numbers reported in other studies (Raw, 1956).

(Continued)

III. Pauropoda (1 species)



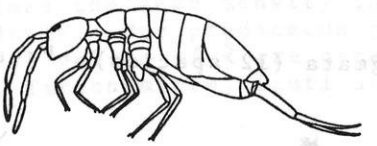
IV. Chilopoda (2 species)



V. Diplopoda (2 species)

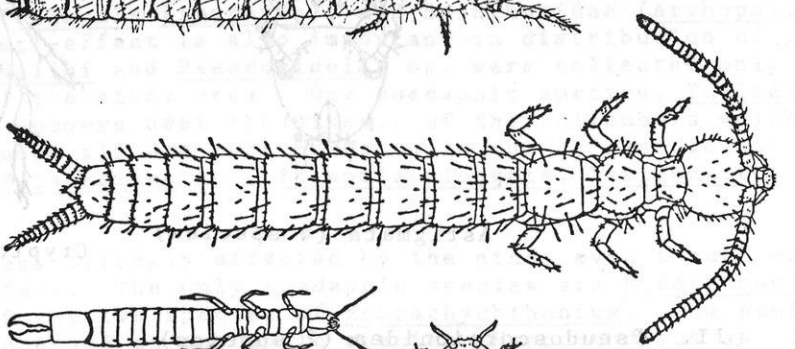
VI. Insecta

A. Collembola (26 species)



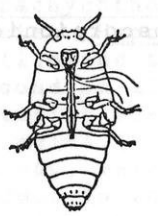
B. Protura (2 species)

C. Symphyla (1 species)

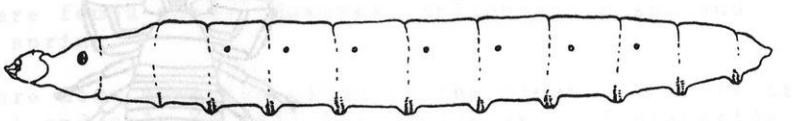


D. Entrophi (2 species)

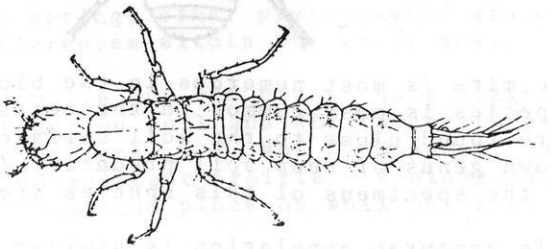
E. Homoptera (2 species)



F. Diptera (5 species)



G. Coleoptera (6 species)



Of the 425 specimens collected in Curtis Prairie, 1970, 93% are Eosentomon sp., the other 7% are Acerella barberi. The common species in Rothampsted Park (Proturentomon maximum) contributed 85% of the individuals, the less common species (Eosentomon armatum), 15%. In both cases, the numbers are much greather than usual in grasslands (Davis, 1963; Salt, et. al. 1948; Sheals, 1957).

In general, this picture of a soil fauna is one of numbers decreasing by a third between the surface and 9 cm. The hemiedaphic stratum of the population contains more species and is slightly more aggregated; it grades into a euedaphic stratum of fewer species which are slightly less aggregated, but more frequent and abundant. Most species are distributed relatively evenly throughout the study area. Maggots, aphids, and astigmatid mites are most variable in occurrence. During the course of a season, the population doubles in numbers, shows an increasing response to proximity to the Leopold Pines, with fewer individuals and species found near the prairie margin, and more aggregated species in the prairie center.

In comparison with other grassland soil arthropod populations, the Curtis Prairie has fewer individuals, but comparable numbers of species. In a Michigan old-field, hickory trees and swales changed soil arthropod species composition, but not individual density or aggregation, as did the stand of pines in the Curtis Prairie. Whether or not the species collected in Curtis Prairie are characteristic grassland species is not known, but the phenology of species living at different levels in the soil is a good example of adaptation to the prairie microhabitat.

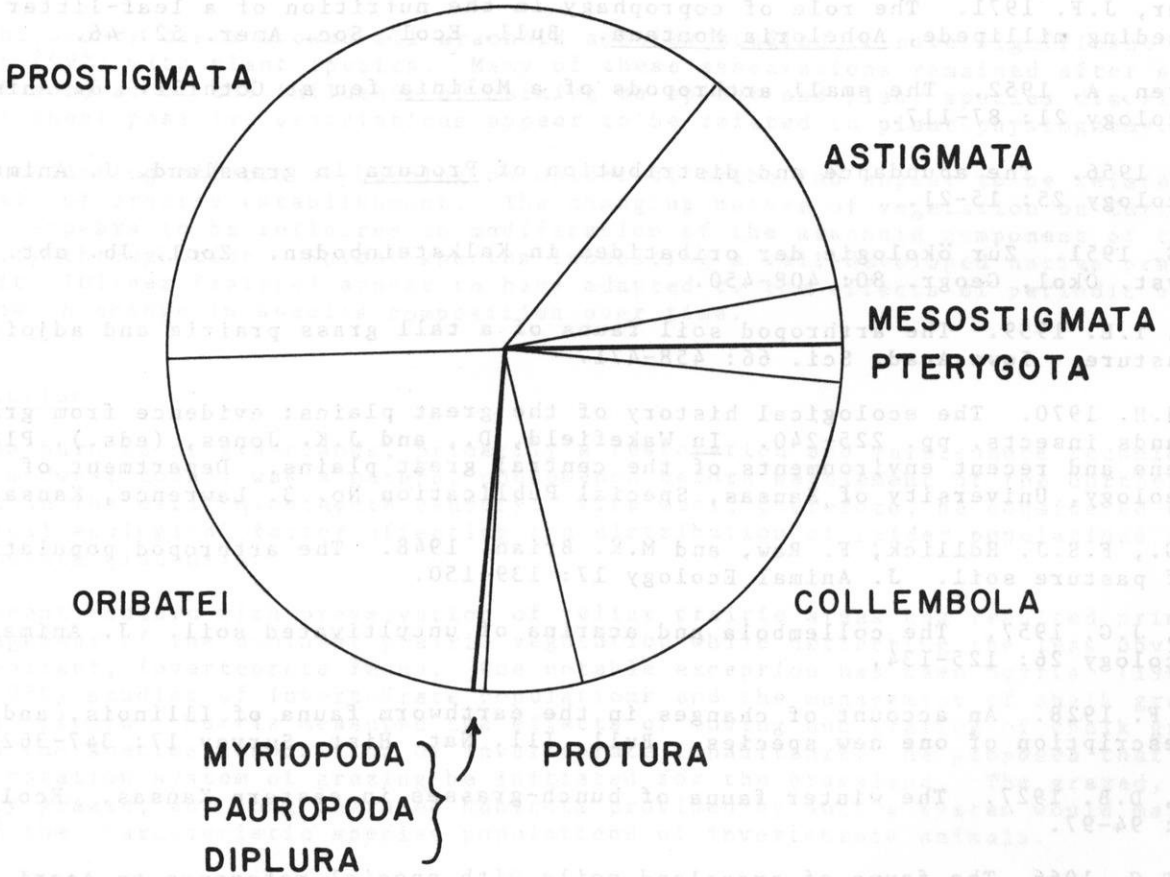


FIGURE IV

Proportion of Individuals in Major Soil Arthropod Groups in Curtis Prairie
2 November, 1969

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EFFECTS OF FIRE ON SPIDER DISTRIBUTION IN SOUTHWESTERN WISCONSIN PRAIRIES

By

Susan E. Riechert

and

William G. Reeder

Department of Zoology, University of Wisconsin
Madison, Wisconsin

ABSTRACT

The effects of burning on spider population composition and distribution was assessed on two prairies in southwestern Wisconsin. Seasonal activity patterns largely determine the different responses of spider populations to immediate effects of burning. Soil and surface temperatures recorded during a burn on Curtis Prairie in the University of Wisconsin Arboretum and the changes in species composition observed following burns on Curtis and Oliver Prairies indicate that species active on the surface at the time of burning are eliminated, while those occupying subsurface burrows or sacs under rocks or in clumps of dense vegetation escape thermal damage. Pitfall trap captures suggest that movement of individuals occurs following a burn between burned and unburned patches of prairie. The burned section of one prairie was largely inhabited by vagrants and other spiders which select areas of lesser cover on unburned prairie, while those species with higher moisture requirements and needing structural features for web production apparently moved onto the unburned section. No movement of spiders from the prairie onto surrounding monotypic agricultural lands was detected.

Chi square tests showed all arachnid species studied to have significant associations (99%) with plant species. Many of these associations remained after statistical removal of the influence of burning on spider and plant species distributions. Some of these positive associations appear to be related to plant physiognomy.

The lasting effects of burning on spider distribution appear to be related to the state of prairie establishment. The changing nature of vegetation on Curtis Prairie appears to be reflected in modification of the arachnid component of the community through time. Spider species inhabiting a well-developed native prairie community (Oliver Prairie) appear to have adapted to the effects of periodic burning and show no change in species composition over time.

Introduction

The burning of grasslands, primarily a restoration and maintenance technique in the midwest today, was a natural phenomenon before settlement of the northern midwest in the early nineteenth century. Fire must, therefore, be considered an historical ecological factor affecting the distribution of spider populations in southwestern Wisconsin.

Recent concern with preservation of relict prairie areas has resulted primarily in management of the dominant prairie vegetation while neglecting the less obvious, but important, invertebrate fauna. One notable exception has been Morris' (1967, 1969, 1970) studies of invertebrate populations and the management of chalk grassland in Britain. Morris measured the effects of mowing and grazing of chalk grassland on the species composition of invertebrate inhabitants. He proposed that a double rotation system of grazing be initiated for the grassland. The grazed, recently grazed, and long ungrazed habitats provided by such a system would maintain most of the characteristic species populations of invertebrate animals.

The ecological significance of fire on limestone and other short grassland plant communities has been assessed (Curtis and Partch, 1948; Dix and Butler, 1954; Wright and Klemmedson, 1965; Daubenmire, 1968; Lloyd, 1968). It is generally accepted that burning has pronounced effects on the vegetative composition of short grass prairies; the specific effects are various and dependent on the plant species involved, the nature of the substrate, and the timing and intensity of the burn.

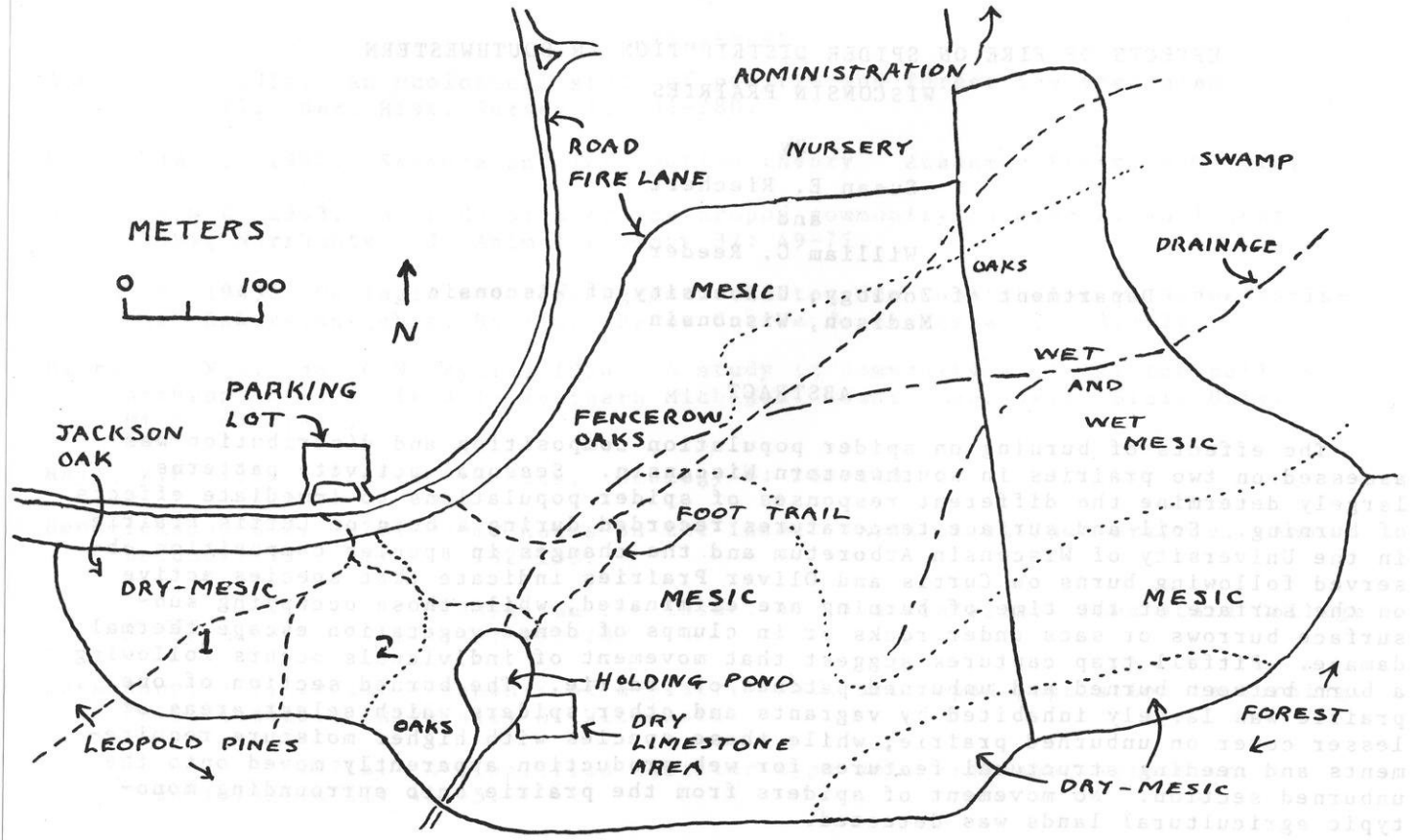

FIGURE I

Map of Curtis Prairie in the University of Wisconsin Arboretum showing the locations of the quadrat study area (1) and the thermocouple grid (2). (Adapted from Cottam and Wilson, 1966, and Reich, 1971; see map section for Arboretum location. Areas 1 and 2 within a homogeneous stand of dry-mesic vegetation.)

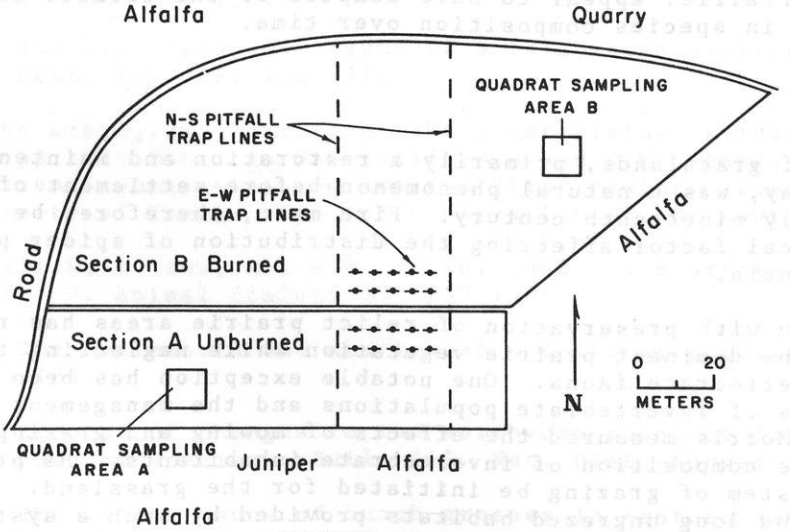

FIGURE II

Map of Oliver Prairie in Green County, Wisconsin showing the locations of quadrat sampling areas, pitfall trap positions and surrounding habitats. The land slopes steeply N, NW and W down to the road.

Studies dealing with the effect of habitat burning on resident invertebrates have largely involved the management of a small number of insect pest species in monotypic agricultural and forest habitats (Campbell, 1961; Lilly and Hobbs, 1962; Crawford and Harwood, 1964; Tippins, 1964). Early spring burning was found effectively to decrease the numbers of undesirable insects (among others) through destruction of large numbers of overwintering larvae and eggs. In at least one study (Lilly and Hobbs, op. cit.), burning was found to destroy the natural predators of pest species as well. Observations have been made on invertebrate faunal changes resulting from accidental fires in forest and grassland vegetation. These studies have provided the expected observation that numbers of invertebrates decrease following a burn. Heyward and Tissot (1936) found a significant decrease in numbers on a burned plot of New Jersey pine forest one year after a fire, while Pearse (1943) and Buffington (1967) in similar studies found not only a decrease in numbers of individuals in burned plots but a decrease in taxonomic diversity as well. Burning was found to cause a steep decline in oribatid mites of European woodlands (Karpinnan, 1957). It has also been held responsible for impoverishment of tropical African soils, in part through destruction of termite populations (Chevalier, 1948). The deleterious effect of burning on invertebrate populations is selective, however, and its effect varies among species. In a burned woods, Huhta (1965) observed that populations and species diversity were reduced, but that a few species, principally grassland forms, had increased in abundance. Coults (1945) found that a majority of the invertebrate species populations in the top inch of South African veldt soil survived burning.

Apparent evolutionary adaptations to periodic burning have been suggested for African grasshoppers and certain other orthopterans, pentatomid bugs, and noctuid larvae (Cowles, 1963; Hocking, 1964). Melanistic forms of these animals inhabit burned-over areas of African savanna; the greater exposure to radiation on burned areas is thought to aid these invertebrates in maintaining a higher preferred temperature (41° C), Joyce (1952).

There appears to be some difference of opinion as to the effect of fire on the aranean component of a community. While Pearse (1943) considered spiders, along with roaches and ants, to be well adapted to existence in a burned area, Rice (1932) and Buffington (1967) thought spiders to be one of the groups least well adapted to burning. It does appear probable, however, that in grasslands subject to periodic burning, fire may be responsible for some of the distributional patterning observed for spiders.

The present study was conducted in order to determine both immediate and longer term effects of burning on spider distribution in a prairie and discern factors controlling the observed compositional changes.

Study Areas

Two study areas were selected for investigation. Preliminary work was conducted on Curtis Prairie in the University of Wisconsin Arboretum, Dane County, Wisconsin; the comparative study was made on Oliver Prairie, Green County, Wisconsin. For the former area, presettlement land survey records (1833-1834) depict the forty acre tract as an oak opening consisting of prairie grasses dispersed among occasional clumps of open-grown Bur and White Oak. Prior to restoration as a prairie in the 1930's, the area had been repeatedly plowed for twenty years and then used as a horse pasture for an additional thirteen years; the field was described in 1935 as consisting of "hopeless clumps of earth in a tangle of brush and thistle" (Sachse, 1965).

Restoration involved the planting of seeds and establishment of strips of prairie sod containing relict prairie plants on the plowed forty acres. Due to diversity in topography, drainage, and soil type on the Curtis tract, plants representing most of the prairie types found in Wisconsin were able to grow, providing, with maturity, a prairie gradient from wet to dry-mesic (Figure I). Regular burning of Curtis Prairie was initiated in 1952 in a successful effort to reduce competition between the late-growing native prairie species (especially the grasses Sorghastrum nutans, Andropogon gerardi, and A. scoparius), and the earlier-growing non-native bluegrasses (Poa compressa, P. pratensis, Agrostis alba), according to Arboretum records. One third to two thirds of the tract is burned in a given year, usually during April. The tract contains a mixture of exotic and native grasses, and prairie forbs and Eurasian field weeds (Cottam and Wilson, 1966).

Since the effect of burning on spider populations on Curtis Prairie is complicated by vegetative diversity and possibly persistent effects of management practices, a smaller and more nearly homogeneous natural prairie was used as a comparison. Oliver Prairie, in Green County, Wisconsin (T3N,R8E,S36 SW1/4; Figure II), known also as "Shooting Star Hill," is a four acre tract of dry lime prairie containing approximately 100 species of plants of various geographical origins. Its plants range from Dropseed (Sporobolus heterolepis), Grama grasses (Bouteloua curtipendula) and Andropogon and Sorghastrum, thought to have originated in the arid southwest, to Shooting Star (Dodecatheon meadia) and Cinquefoil (Potentilla arguta), common in the eastern states (H.H. Iltis, personal communication). By far the largest group of plants of this prairie, however, include species endemic to midwestern prairies. Oliver Prairie can be considered dry-mesic in that many of its plant species (e.g., shooting star), have average moisture requirements. Plants adapted to more xeric conditions with a lesser soil base and greater runoff are also present on parts of the hill where limestone is exposed, for example, the native Muhlenbergia cuspidata and the Eurasian Poa compressa (the only conspicuous exotic).

Most lime prairies in Wisconsin were destroyed by commercial lime removal, but the former owners of Oliver preserved it for its botanical value. The tract was obtained by the Wisconsin Nature Conservancy in 1962; burning was introduced as a maintenance practice in 1962 and was repeated in 1965 and 1969.

Materials and Methods

A 25 m^2 grid was staked out in the western section of Curtis Prairie (Figure I, location 1), described in terms of vegetation as dry-mesic (Cottam and Wilson, 1966). Sampling points within the grid were selected by use of a table of random numbers; 25 samples were taken from the grid on each of the following dates: 19 April 1967, 8 June 1967, 30 March 1968 (before burn), 1 April 1968, 6 April 1968, and 6 June 1968.

Samples were taken by placing an 0.25 m^2 aluminum frame (Figure III) on the area to be sampled. The frame was fixed at the sampling point; vegetation and litter were removed to a plastic bag from the area within the frame. Spiders observed within the frame were hand-caught and immediately preserved. Those organisms remaining were retrieved by handsorting in the laboratory.

Arboretum workers burned the dry-mesic section of Curtis on 30 March 1968. A record of burn intensity and duration at one site was made during this burn. Iron-constantan thermocouples were placed at the following depths: surface, 0.5 cm below surface, and 1.0 cm below surface. Temperatures were monitored continuously using a Honeywell Electronik recording potentiometer.

Oliver Prairie was divided into two sections: the southern section (A) containing one third, and the northern section (B) containing two thirds of the area (Figure II). The latter section was burned on 24 April 1969: the southern section was left as an unburned control. Quantitative samples, using methods described above for Curtis Prairie, were made on 10 June 1968, 19 April 1969, 25 April 1969, 11 May 1969, 23 May 1969, and 11 June 1969.

In addition, 23 pitfall traps were positioned 10 meters apart on two north-south transects on the prairie. These traps were checked on the following dates: 5 May 1969, 11 May 1969, 16 May 1969, 20 May 1969, 23 May 1969, 27 May 1969, 2 June 1969, and 9 June 1969. Four east-west transects including a total of twenty pitfalls were positioned across the interface between the burned and unburned areas (Figure II). These were checked on: 27 May 1969, 2 June 1969, and 9 June 1969.

Plant species present and percent cover were recorded on 0.25 m^2 quadrats centered on each pitfall position. Point sampling was used to determine vegetational composition and cover on quadrat sampling areas A and B.

Method of Analysis

Analyses of homogeneity among samples collected in different areas and at different times were completed by application of chi square and non-parametric rank sum tests. Chi square tests were performed a) on samples collected periodically from Curtis Prairie, b) for comparison of burned and unburned samples from Oliver Prairie, and c) to test for associations between plant and spider species from Oliver Prairie.

The technique of factor removal (Beals, 1965) was used in order to find correlations between plants and spiders in addition to those caused by the burning. A modified, non-parametric rank sum test (Mood, 1950) was used to compare numbers of individuals between the two sections of Oliver Prairie.

Results and Discussion: Curtis Prairie

In order to learn the nature and significance of differences between samples taken on Curtis prior to and following the burn of 30 March 1968, chi square comparisons of the sampled populations were made (Table 1). The results indicate highly significant differences (99%) in species composition and numbers of individuals between samples taken at 8 a.m. prior to the burn of 30 March and those taken at 8 a.m. one week after burning. This difference in composition was not immediate however, in that, although severe reduction in numbers of individuals was noted immediately following the burn, species composition appeared to remain stable. No new taxa were added in the samples collected the morning after the burn (April 1) and differences in species composition between samples taken prior to the burn on 30 March and those of April 1 were insignificant (Tables 1 and 2). Although within one week after the burn numbers of individuals had increased to levels observed before the burn, the species composition had modified from that in the preburn samples. Preburn samples contained 21 arachnid species, while 32 were obtained from the post-burn sampling of April 6th. Four species found prior to the burn were absent in the post-burn samples, 4 species decreased considerably in number, while 17 additional species were found on the plot within a week after the burn (Table 2).

It is uncertain whether this increase in numbers of species and individuals on the plot within a week after the burn resulted from an influx from surrounding areas, or whether the spiders were continuously present on the plot but were missed in the sampling due to inactivity and residence in the soil beneath the sampled litter. Shelford (1913) mentioned as one of the striking features of the prairie fauna, the apparent absence of invertebrates in winter. This phenomenon was demonstrated by Hayes (1927) to be a result of the burrowing tendencies of many prairie invertebrates to escape the harsh winter environment. The spring of 1968 was marked by unseasonably cold temperatures; it is thus possible that the majority of spiders had not yet emerged from their overwintering sacs and burrows prior to the burn. The observed decrease in many of the web building species (Table 2) would be expected because surface active individuals, unprotected by clumps of vegetation, would likely be eliminated. The temperature record of the burn (Figure VII) suggests that individuals of species occupying subsurface burrows or sacs under rocks or within tufts of bunch grass would probably escape thermal damage. The bunch grasses of dry prairies characteristically possess dense crowns extending up to two inches above the soil surface. These crowns are formed by compression of the meristems and bases of individual grasses and are permanent parts of the clonal species (Weaver, 1968). Due to its extreme density, the compact crown is not affected by fire. Sac spiders and dwarf spiders have been found living in these within 30 minutes after a burn. It is probable that other spiders inhabiting crowns would survive a fire as well.

An earlier phenology in prairie vegetation has been observed in burned areas. Here, the plants tend to bloom earlier than members of the same species in unburned areas (Hensel,1923; Rice, 1932; Martin, 1966). Dark ash and lack of litter on the burned section may result in unequal heat retention of burned versus unburned soils (Pearse, 1943). Spiders surviving the burn by virtue of their position below the soil surface appear to emerge earlier than individuals of the same species on adjacent plots. This modification in spider phenology in the form of earlier activity due to higher soil temperatures could explain the appearance of fifteen additional species on the burned plot several days after the burn.

Oliver Prairie

In 1969 sampling was extended to the smaller and more nearly homogeneous Oliver Prairie. A chi square test performed on two groups of samples taken from Oliver on 19 April 1969 prior to burning showed sections A and B to be homogeneous in spider composition. Likewise, a Mood ranked non-parametric sum test exhibited no significant differences between the two plots beyond random variation in numbers of individuals (Table 3).

Table 1: Chi-square Tests of Species Composition and Numbers, Curtis Prairie

	8 June 1967	30 March 1968	1 April 1968	6 April 1968	6 June 1968
8 June 1967		X	X	X	significant at 99%
30 March 1968	X		non-sig.	non-sig.	X
1 April 1968	X	non-sig.		non-sig	X
6 April 1968	X	sig. at 99%	non-sig.		X
6 June 1968	sig. at 99%	X	X	sig. at 99%	

Table 2: Change in Spider Species Composition on Curtis Prairie Following a Burn. + = New Species Added After the Burn, 0 = Those Species Disappearing Entirely After the Burn, and - = Those Species With a Significant Decrease in Numbers After the Burn.

		30 March AM	1 April AM	9 April AM
WEB BUILDERS				
Theridiidae				
Euryopis limbata (Walckenaer)	0	frequent	absent	absent
Theridion frondeum (Hentz)	-	abundant	rare	frequent
Theridion sp.	+	absent	absent	rare
Linyphiidae				
Helophora insignis (Blackwell)	+	absent	absent	abundant
Lepthyphantes nebulosa Sundevall	0	rare	absent	absent
Linyphia clathrata Sundevall	-	abundant	rare	rare
Micryphantidae				
Ceraticelus emertoni (O.P. Cambridge)	-	frequent	absent	rare
Ceratinops crenata (Emerton)	0	rare	rare	absent
Hypselistes florens (O.P. Cambridge)		rare	absent	rare
Walckenaer vigilax (Blackwell)	+	rare	absent	abundant
Tetragnathidae				
Tetragnatha seneca Seeley	+	rare	absent	abundant
Uloboridae				
Uloborus sp.	+	absent	absent	rare

VAGRANTS (see next page)

Table 2: Continued

VAGRANTS				
Clubionidae				
Clubiona abbottii L. Koch	0	rare	rare	absent
Clubiona sp.	-	abundant	rare	rare
phrurotimpus minutus Banks		rare	absent	frequent
Gnaphosidae				
Gnaphosa sericata (L. Koch)	+	absent	absent	rare
Gnaphosa sp.	+	absent	absent	rare
Haplodrassus sp.		rare	rare	rare
Poecilochroa capulata (Walckenaer)		rare	absent	rare
Anyphaenidae				
Anyphaenella saltabunda (Hentz)		rare	absent	rare
Lycosidae				
Pardosa sp.		frequent	rare	abundant
Pirata minutus Emerton		rare	rare	abundant
Pirata sp.	+	absent	absent	rare
Hahniidae				
Neoantistea radula (Emerton)		rare	absent	rare
Salticidae				
Evarcha hoyi (Peckman)	+	absent	absent	rare
Gertschia dakodensis Cutler	+	absent	absent	frequent
Habronattus decorus (Blackwell)		rare	absent	rare
Habrocestum pulex (Hentz)	+	absent	absent	rare
Metaphidippus sp.	+	absent	absent	rare
Onondaga lineata (C.L. Koch)	+	absent	rare	rare
Phidippus rimator (Walckenaer)	+	absent	absent	frequent
Phidippus sp.	+	absent	absent	rare
Dictynidae				
Dictyna coloradensis Chamberlin		rare	absent	rare
Thomisidae				
Oxyptila sp.		frequent	absent	frequent
Tibellus maritimus (Menge)	+	absent	absent	rare
Xysticus sp.	+	absent	absent	rare
Xysticus triguttatus Keyserling		rare	absent	rare

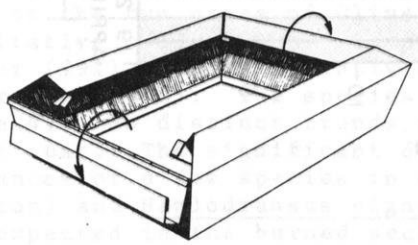

FIGURE III

A diagrammatic representation of the 0.25 m^2 aluminum sampling frame used for collecting quantitative litter samples. Two of the sides are hinged to facilitate raking of the litter and top soil layers. Slanted sides and the overhang at the top of the frame have been designed to hinder arachnid escape.

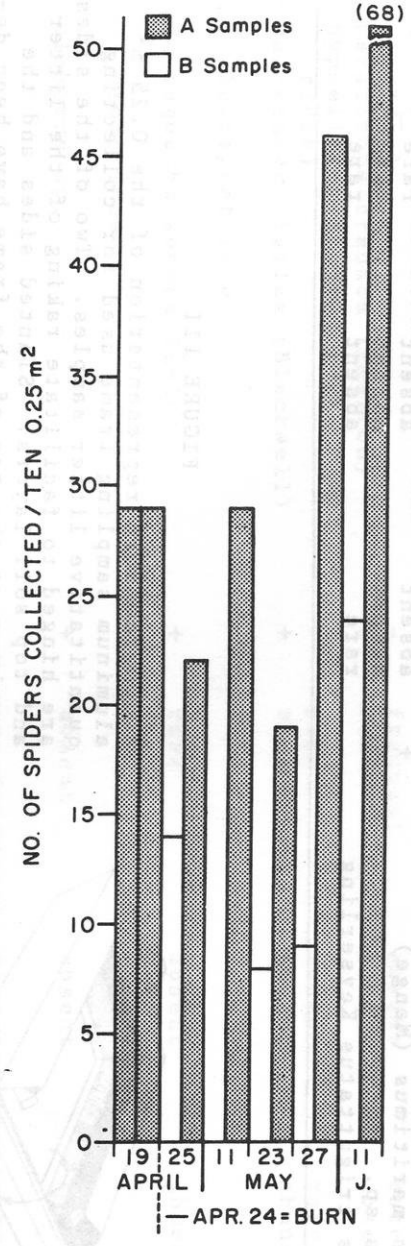

FIGURE IV

Comparison of the numbers of spiders caught per ten 0.25 m samples between burned and unburned sections of Oliver Prairie. Corrections for unequal sample numbers have been made on the basis of relative numbers caught per sample.

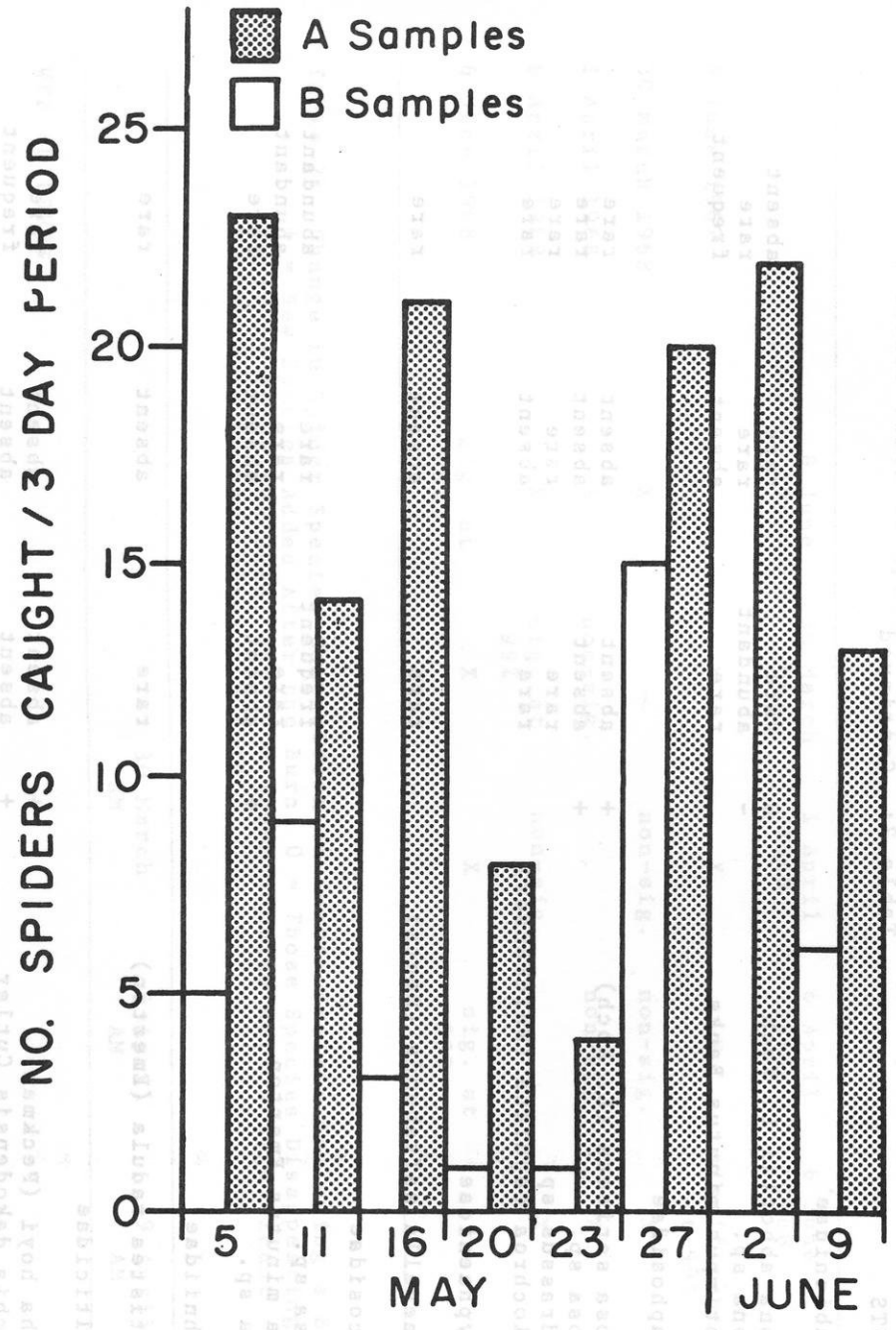

FIGURE V

Comparison of the numbers of spiders collected in N-S pitfall traps per three day period on burned and unburned sections of Oliver Prairie.

After burning, the Mood test comparing samples from section B (burned) with those of A (unburned) indicated a highly significant difference in numbers of individuals. The burned section had an appreciably greater number of null samples than the unburned section as well as fewer samples with large numbers of individuals (Figure IV). These results coincide with those obtained from the pine barren studies, (Heyward and Tissot, 1936; Pearse, 1943 and Buffington, 1967), where the burned area supported smaller numbers of individuals. In part, reduction of individuals on a burned prairie results from mortality, the extent of which varies according to the time of year in which the burn takes place. Such mortality is selective in that those forms present on webs on the vegetation or vagrant on the litter have a higher probability of fatality. Individuals surviving the direct heat are later subjected to changed conditions such as increased diel temperature extremes (Ahlgren and Ahlgren, 1960; Daubenmire, 1968), direct exposure to incident radiation, increased evaporation, and greater soil runoff (Buffington, 1967); these conditions are largely due to litter loss and ash residues. Furthermore, the destruction of litter may entail the loss of structural characteristics necessary for certain species to build webs or other wise utilize the habitat. Thus species least adapted to meet these changed conditions would be expected to decrease in abundance, while those better adapted should increase.

The greatest decrease in numbers on Oliver Prairie was observed two weeks after the burn (Figure IV); no spiders were found on May 11 in the burned section (B), while section A contained an average of 3.2 spiders per 0.25 m^2. This suggests that spiders, having survived the burn, decreased in numbers either by emigrating, moving more deeply into the soil, or through mortality under the changed ambient conditions. This observation agrees with results seen on Curtis Prairie in 1968, but unlike that example, the burning of Oliver came after a comparatively mild spring. Thus, many of the spiders normally present in spring and early summer had been recorded in pre-burn sampling, and there appeared to be no large influx of newly emerging species. Rather, after an initial decrease occuring approximately two weeks after the burn, a slow increase in numbers in the burned section was apparent. The numbers collected over a 45 day period in the burned section, however, did not approach those collected in the unburned section (Figure IV).

Thus, the differing results from Curtis and Oliver Prairies may be due to dissimilarity in weather conditions on the two prairies prior to and at the time of burning. Few spider populations were active prior to the burning of Curtis Prairie in late March of 1968, while a large number of species were active on Oliver Prairie prior to the burning in late April of 1969.

Chi square tests showed species composition between burned and unburned samples at Oliver Prairie to be significantly different at 95%. Significantly greater numbers of immature Phidippus spp., Schizocosa spp., and Tibellus oblongus (Walckenaer) were found on the burned section than expected (Table 3). On the other hand, Onondago lineata (C.L. Koch), Sitticus floridanus Gertsch and Mulaik, and Theridion dividuum Gertsch and Archer were absent on the burned section (B); two of these species frequented both sections of the prairie before the burn and all frequented the unburned section (A) afterward. In part the increase of Phidippus on the burned area is related to the abundance of Dodecatheon meadia in bloom there. Dodecatheon had an average cover of 26.5 cm /0.1 m and relative frequency of 3.4% on section A, while on section B its average cover was 36.45 cm /0.1 m and relative frequency, 11.5%. Individuals of Phidippus were observed on Dodecatheon inflorescenses on 32 separate occasions during the two month study period. No explanations for the other highly significant changes in spider distributions were obvious, however.

Chi square tests and rank sum tests performed on spiders collected in pitfall traps on the two areas of Oliver Prairie produced results similar to those from the quantitative collections. Samples from the unburned section contained significantly greater (99%) numbers of individuals than did those from traps in the burned section (Figures V and VI). The species complement also differed (99%) between the two areas. (Table 4). No distinct trends in sample differences could be seen from one sampling to the next. The significant difference in species composition was due to unexpected abundances of a few species in one or the other area. Schizocosa crassipalpis (Emerton) and Haplodrassus signifier (C.L. Koch) had greater frequencies of capture than expected in the burned section, while Thanatus formicinus (Clerck) was found to be far more abundant in the unburned area. Pardosa distincta (Blackwell) was collected only in the unburned section.

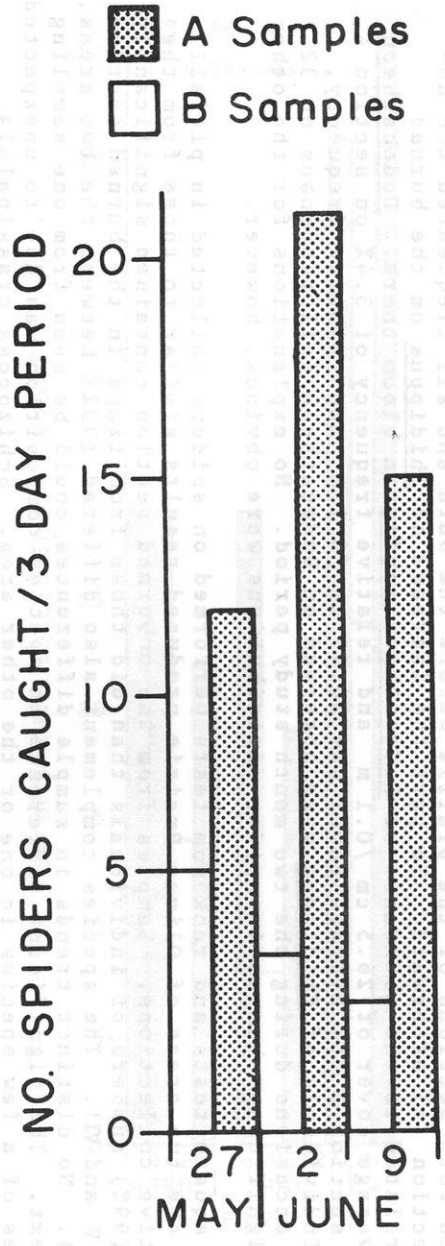

FIGURE VI

Comparison of E-W transect pitfall trap captures per three day period on burned and unburned sections of Oliver Prairie.

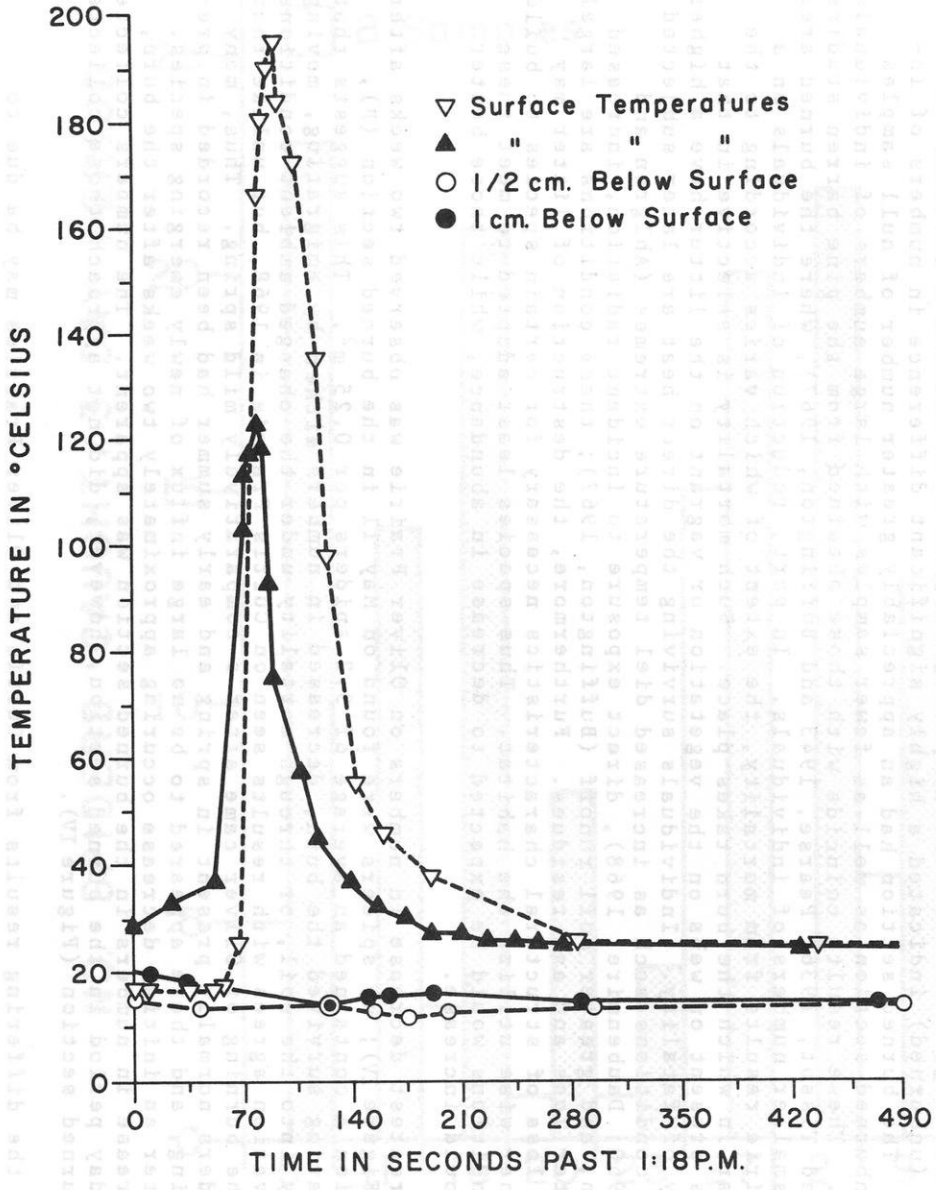

FIGURE VII

Temperature record of a Curtis Prairie burn, 1:15 PM, 30 March, 1968. Temperatures were recorded at surface, and 0.05 cm below surface, on the dry-mesic section of Curtis Prairie, University of Wisconsin Arboretum.

Table 3: Comparison of Spider Species Composition Between Burned and Unburned 0.25 m^2 Samples on Oliver Prairie.

	19 APR		24 APR	25 APR		11 MAY		23 MAY		27 MAY		11 JUNE	
	A	B	Burn	A	B	A	B	A	B	A	B	A	B
Theridiidae													
Crustulina altera Gertsch & Archer				R							F		
Crustulina sticta (O.P. Cambridge)					R								
*Theridion dividuum Gertsch & Archer										Abd		R	
Theridion sp.						R							
Linyphiidae													
Helophora insignis (Blackwell)						R							
Lepthyphantes sp.	R												
Meioneta unimaculata (Banks)	F					R							
Microneta (new species)				R	R	F			R	F			
Microneta viaria (Blackwell)	F				F		R						
Micryphantidae													
Ceraticelus laticeps (Emerton)													F
Erigone (new species)										F	F		R
Scylaceus pallidus (Emerton)					R								
(new genus, species)										F			
Argiopidae													
Araniella displicata (Hentz)										R		Abd	F
Tetragnathidae													
Pachygnatha kuratai Levi		R											
Tetragnatha sp.								R					
Clubionidae													
Clubiona johnsoni Gertsch		R				R		F					
Clubiona sp.	Abd	Abd			F				R				R
Phrurotimpus borealis (Emerton)	R						F						
Gnaphosidae													
Gnaphosa sericata (L. Koch)								R					
Haplodrassus signifier (C.L. Koch)										F			
Poecilochroa capulata (Walckenaer)										R			
Lycosidae													
Lycosa frondicola Emerton						R							
Pardosa distincta (Blackwell)								R		F			
Pirata minutus Emerton	R												
Schizocosa crassipalpis (Emerton)	R									Abd			
*Schizocosa sp.				R	F	F				F	R		
Salticidae													
Gertschia dakodensis Cutler	R	R		R		R				R			
Habronattus sp.	R					R	R					F	
Metaphidippus protervus (Walckenaer)	F	Abd			R					F		Abd	F
*Phidippus rimator (Walckenaer)									F	R	F	Abd	Abd
*Onondaga lineata (C.L. Koch)	R	F		R									

continued next page

Table 4: Comparison of N-S Pitfall Trap Collections Between Burned and Unburned Sections of Oliver Prairie. A = Unburned B = Burned sections

	5 MAY		11 MAY		16 MAY		20 MAY		23 MAY		27 MAY		2 JUN		9 JUN	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Theridiidae																
Theridion dividuum Gertsch & Archer				R												
Linyphiidae																
Meioneta unimaculata (Banks)			R								F			R		
Microneta (new species)				R				R			R	R		R		
Micryphantidae																
Ceraticelus emertoni (O.P. Cambridge)											R					
Ceratinops crenata (Emerton)	R	R				R	R				R	R	R			
Eridone (new species)	R										R			R		
Scylaceus pallidus (Emerton)			R													
Argiopidae																
Araniella displicata (Hentz)													R			
Pachygnatha kuratai Levi			R													
Clubionidae																
Phrurotimpus borealis (Emerton)			F													
Gnaphosidae																
Callilepis imbecilla (Kerserling)															R	
*Haplodrassus signifier (C.L. Koch)					R				R			F	R	R		R
Zelotes hentzi Barrows			R													
Zelotes sp.			R	R												
Lycosidae																
Arctosa emertoni Gertsch		R					R									
Lycosa avida Walckenaer	R										R		R			
*Lycosa frondicola Emerton	F	R	F	R	Abd		R		R		R		F		R	R
*Pardosa distincta (Blackwell)	F		R								R				R	
Pardosa sp.	R											R				R
*Schizocosa crassipalpis (Emerton)									R		R	Abd	Abd	Abd	Abd	F
Schizocosa sp.	F		R									R	F	R		
Schizocosa saltatrix (Hentz)							R									
Lycosa pratensis Emerton	R											R				R
Salticidae																
Sitticus floridanus Gertsch & Mulaik			R													
Talavera minuta (Banks)													R			
													R			
Thomisidae																
Oxyptila sp.	R															
*Thanatus formicinus (Clerck)	F		R	R	F	R	R				R				R	
Tibellus oblongus (Walckenaer)											R					
Xysticus bicuspis Keyserling	R		R	R	R		R	R			F		R			
Xysticus discursans Keyserling							R				R			R		
Xysticus luctans (C.L. Koch)											R		R		R	

R = rare
F = frequent
Abd = abundant
* Those species whose numbers contributed significant values to chi-square tests.

Some species may be indirectly affected by a burn through changes in the nature of plant cover. This possibility was discussed by Duffey and Morris (1966) who suggested that, although the greater insulation provided by plant cover would be important for some animals, other spiders would show greater activity on open ground where hunting could be conducted under unobstructed conditions. The discrepancy on Oliver between plant cover on burned (67%) and unburned sections (99%), measured two months after the initial burn, permitted study of the effect of cover in determining distribution of certain spiders. Two species of the family Lycosidae were distributed in relation to amount of cover. Lycosa frondicola Emerton was consistently found on unburned sections inhabited by species exhibiting high cover values either by virtue of structural features or density. In the burned section Lycosa frondicola was almost always found in areas of unusual plant density. On the other hand, Schizocosa crassipalpis (Emerton) showed a preference for reduced cover. The species had a 99.5% negative association with those plant species yielding a higher percent cover and had a highly significant rate of capture in the burned section. Both species behaved similarly in laboratory observations (enclosure size 6.25 m^2); Lycosa selected areas of greater cover, and Schizocosa preferred burned and mowed sod to the regular prairie litter.

Nine of the most frequently trapped spider species were tested for possible associations with plant species having a frequency of occurrence greater than 5% within a 0.25 m^2 area surrounding each pitfall trap at Oliver Prairie. Forty-eight positive associations between species of plants and spiders were found at a significance of 95% or greater (Table 5), while only two significant negative associations were found.

The question is, how much of this observed association is a result of reactions to similar factors by both plants and spiders? This problem was in part avoided by using Beals' method of factor elimination to remove associations due primarily to the effect of burning on species distribution. Beals (1965) found that associations due to common or different preferences of an environment could be removed, if the factor was measured in each sample. In the present study, samples were grouped as to whether they were taken in the burned or unburned section of Oliver Prairie, and expected values of joint occurrences for each section were then calculated and summed. Chi square tests of 2 x 2 contingency tables using these new expected values determine whether factors besides the removed burn factor are affecting the relationships between species.

After removal of the burn factor, 2 associations increased in significance, 23 associations remained the same, 9 associations decreased but were still significant and 16 associations decreased below significance. Thus 50% of the associations decreased upon removal of the burn factor and 32% of them decreased below significance levels (Table 5). Over half of the plant and spider correlations on the prairie, therefore, were influenced by burning.

Nevertheless, all of the arachnids studied still retained some degree of significant association with certain plant species after the burn factor had been removed. The observed associations do not necessarily imply a direct causal relationship. For example, secondary association with plants may be brought about by the presence of specific insects on the plants. There might also be an association with physiognomic or structural features of the plants themselves. Patterns of insect presence and density were not followed closely enough on the prairie to answer questions concerning their importance in influencing spider distribution, but certain structural features were measured in each of the plant species and these have been compared. The structural features measured were internodal distance, number of divisions per branch, extent of hairiness leaf type, leaf shape, leaf length, and presence or absence of inflorescence at time of sampling.

Structural features held in common by all or most of the plant species showing positive associations with a given species were considered possible features used or "selected" by the spider. In this manner Haplodrassus signifier (C.L. Koch) was found to be associated largely with plants having sessile or clasping linear leaves, while Micronetа (sp. nov.) was found associated with plants possessing few divisions per branch and medium sized leaves (averaging 5.3 cm). Thanatus formicinus (Clerck) "selected" petioled plants with a long leaf length, 13 cm, and Xysticus luctans (C.L. Koch) was found associated primarily with glabrous plants.

Total cover provided by the plant may be more important to the ground spider than the structural features of the plants themselves. Average cover associated with Lycosa frondicola, Microneta (sp. nov.) and Ceratinops crenata Emerton ranged between 6 and 7.5 cm^2 of ground per 1% frequency of the plant, (an average obtained from frequency in a 0.25 m^2 area). An exception was Poa compressa, the lesser cover of which (0.64 cm^2 per 1% frequency) was balanced by its high frequency of occurrence at least in the unburned section. It is apparent that plant structure may explain some of the distribution of spider populations of Oliver Prairie, but certainly not all.

Lasting Effects of Burns on Spider Distribution

A comparison of samples on two successive years at both Curtis and Oliver Prairies produced no conclusive results as to long range effects of burning on prairie spider distribution.

A comparison of samples collected in June 1967 on Curtis Prairie with those collected the following year showed the two sample groups to be significantly different at 99% in species complement and in numbers (Table 1). On the other hand, comparisons of samples taken in June of 1968 showed no significant differences in the groups at Cliver. Thus at Oliver, despite the fact that burned and unburned samples were significantly different from one another in June 1969, neither sampling group was found to be significantly different from samples taken in June of 1968.

The conflict in results observed for these two prairies can be explained in part by the nature of the prairies. Curtis Prairie has been shown to be intermediate between a weed community and a "true" prairie, as determined by the relative frequencies of native prairie species and competing European weeds (Cottam and Wilson, 1966). Plant surveys taken at five-year intervals have shown the prairie to be changing from a community dominated by weeds to one with increased dominance of introduced native species. It is thought that the spider distribution on this prairie is in a similar state to that evidenced in the plant studies, in that the two years of censusing of Curtis Prairie have shown the spider community to be composed of a large number of species populations found on any grassland in southwestern Wisconsin along with some species more frequent or unique to relict prairies in Wisconsin as well as some contributions from the Western Plains prairies. Although burning may enhance the transformation rate of the arachnid component on the drymesic section of Curtis Prairie, changes in composition probably would occur regardless of the burn factor, since change is inherent in the non-equilibrium state of Curtis Prairie.

Oliver Prairie, unlike Curtis Prairie, has rather stable vegetation, a compact community of native prairie plant species that remains intact despite the presence of a weed community in the adjacent quarry and alfalfa fields. Results of this study suggest that the abundance and species composition of spiders on Oliver Prairie are relatively stable and that species inhabiting the prairie have adapted to the effects of periodic burning.

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Table 5: Plant and Spider Species Association Before and After Removal of the Burn Factor

	χ^2	Significance Prior to Burn Factor Removal	Significance After Burn Factor Removal
*Ceratinops crenata			
Amorpha canescens (Lead Plant)	16.7	99.5%	99.5%
Coreopsis palmata (Prairie Tickseed)	9.0	99.5%	99.5%
Euphorbia corollata (Flowering Spurge)	4.3	95.0%	99.5%+
Helianthus rigidus (Prairie Sunflower)	16.1	99.5%	99.5%
Monarda fistulosa (Wild Bergamot)	9.0	99.5%	99.5%
Phlox pilosa (Phlox)	6.5	97.5%	99.5%+
Stipa spartea (Porcupine Grass)	4.3	95.0%	95.0%
*Haplodrassus signifier			
Amorpha canescens (Lead Plant)	5.0	95.0%	-
Aster ericoides (Heather Aster)	6.9	99.0%	97.5%
Euphorbia corollata (Flowering Spurge)	11.1	99.0%	99.0%
Panicum leibergii (Panic Grass)	5.9	97.5%	97.5%
Sporobolus heterolepis (Prairie Dropseed)	4.1	95.0%	-
*Lycosa frondicola			
Comandra richardsiana (Bastard Toadflax)	8.0	99.5%	95.0%
Helianthus rigidus (Prairie Sunflower)	12.6	99.5%	99.5%
Liatris aspera (Rough Blazing Star)	3.9	95.5%	-
Panicum Leibergii (Panic Grass)	18.8	99.5%	-
Poa compressa (Canada Bluegrass)	27.9	99.5%	-
Ratibida pinnata (Prairie Coneflower)	13.2	99.5%	-
Solidago rigida (Stiff Goldenrod)	6.3	97.5%	-
*Meioneta unimaculata			
Amorpha canescens (Lead Plant)	6.8	99.0%	95.0%-
Aster sericeus (Silky Aster)	6.2	97.5%	99.0%
Coreopsis palmata (Prairie Tickseed)	4.3	95.0%	95.0%
Poa compressa (Canada Bluegrass)	10.0	99.5%	99.5%
Sisyrinchium campestre (Blueyed Grass)	12.9	99.5%	99.5%
Solidago rigida (Stiff Goldenrod)	8.4	99.5%	99.5%
Sporobolus heterolepis (Prairie Dropseed)	12.9	99.5%	99.5%
*Schizocosa crassipalpis			
Helianthus rigidus (Prairie Sunflower)	10.4	99.5% (NEG.)	-
Poa Compressa (Canada Bluegrass)	16.0	99.5% (NEG.)	-
*Thanatus formicinus			
Comandra richardsiana (Bastard Toadflax)	6.6	97.5%	-
Helianthus rigidus (Prairie Sunflower)	8.1	99.5%	97.5%
Sporobolus heterolepis (Prairie Dropseed)	10.0	99.5%	99.0%
*Xysticus bicuspis			
Amorpha canescens (Lead Plant)	5.3	99.5%	95.0%-
Euphorbia corollata (Flowering Spurge)	7.5	99.5%	99.0%-
Helianthus rigidus (Prairie Sunflower)	17.7	95.0%	99.5%
Liatris aspera (Rough Blazing Star)	12.7	99.5%	99.0%-
Panicum leibergii (Panic Grass)	6.0	97.5%	97.5%
Phlox pilosa (Phlox)	5.1	99.5%	95.0%-
Poa compressa (Canada Bluegrass)	14.6	99.5%	99.0%
Ratibida pinnata (Prairie Coneflower)	4.8	95.0%	-
Solidago rigida (Stiff Goldenrod)	5.0	95.0%	-
*Xysticus discursans			
Amorpha canescens (Lead Plant)	4.8	95.0%	-
Liatris aspera (Rough Blazing Star)	10.7	99.5%	99.5%

Table 5: Continued	χ^2	Significance Prior to Burn Factor Removal	Significance After Burn Factor Removal
*Xysticus luctans			
Amorpha canescens (Lead Plant)	5.5	97.5%	95.0%-
Bouteloua curtipendula (Side-oats Grama)	9.6	99.5%	99.5%
Liatris aspera (Rough Blazing Star)	9.6	99.5%	-
Lobelia spicata (Prairie Lobelia)	9.9	99.5%	99.5%
Poa compressa (Canada Bluegrass)	5.5	97.5%	-
Prenanthes racemosa (Rattlesnake Root)	7.9	99.5%	-
Ratibida pinnata (Prairie Coneflower)	8.1	99.5%	97.5%-
Tragopogon pratensis (Goats Beard)	11.9	99.5%	97.5%

- = those associations decreasing in significance after burn factor removal
+ = those associations increasing in significance after burn factor removal

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THE EFFECTS OF FIRE ON SMALL MAMMAL POPULATIONS IN A RESTORED PRAIRIE WITH SPECIAL REFERENCE TO THE SHORT-TAIL SHREW, BLARINA BREVICAUDA

By

J. Tucker Springer and Peter Schramm

Department of Biology
Knox College, Galesburg, Illinois

ABSTRACT

During the summers of 1969 and 1970, in the course of continuing small animal studies in a restored prairie on the Knox College Biological Field Station, considerable live-trap data were obtained on the short-tail shrew, Blarina brevicauda. In 1969, two study plots (each 105 ft. sq.) with different burning histories were compared. In 1970 three different plots (105 ft. sq.) with different burning histories were compared. We concluded that burning does reduce the density of short-tailed shrews in restored prairie habitat for up to about 1 1/2 years; but by two years plus, after a spring burn, the shrew population is up to densities found in prairie left unburned for four years. It is suggested that drastic reduction of litter in the year following the burn may be a key factor in influencing shrew densities.

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Introduction

Fire, either naturally occurring or man-set, has long been thought to be a frequent and natural phenomenon associated with prairie ecosystems. A great deal is known about the effects of fire on the prairie flora much of which apparently thrives under frequent burning. Much less is known about the effects of fire on associated animal organisms.

This report constitutes part of a continuing study of the effects of fire on small mammal populations in a seven-acre portion of restored prairie on the Knox College Biological Field Station, Knox County, Illinois. The data presented here were collected during the summers of 1969 and 1970.

The purpose of this study was to determine if burning of prairie habitat affects small mammal populations found there; if it does, what the effects are, and, in particular, how long these effects last. This paper deals especially with the effects of fire on a population of the short-tailed shrew, Blarina brevicauda.

Study Area

In 1968, two one-quarter acre study plots were set up--Grid 1 and Grid 2--in a seven-acre restored prairie known as the East Prairie (See "S" in Figure I, Van Petten's paper following, and Figure I herewith). The small mammal populations there were studied that summer by Schramm (1970). These same two grids were studied in 1969. In the spring of 1970, a third grid was set up (Grid 3 - Figure I), and all three areas were studied during the summer of 1970.

Grid 1 was last burned in the spring of 1966 and since that time four years of vegetative growth have accumulated. The lack of fire has noticeably affected the growth of vegetation in this area, with the tall grasses being shorter and with fewer flowering heads than grass in newly burned areas.

Grid 2 was last burned in the spring of 1968 and has since then accumulated two years of vegetative litter. The differences between grasses here and on newly burned areas are readily apparent, though the contrast is not as great as in Grid 1.

Grid 3 was burned in the spring of 1970, and thus had no accumulated litter.

FIGURE I

Map of the East Prairie Showing The Three Grids Studied. Dates Indicate Most Recent Spring Burning for Each Grid.

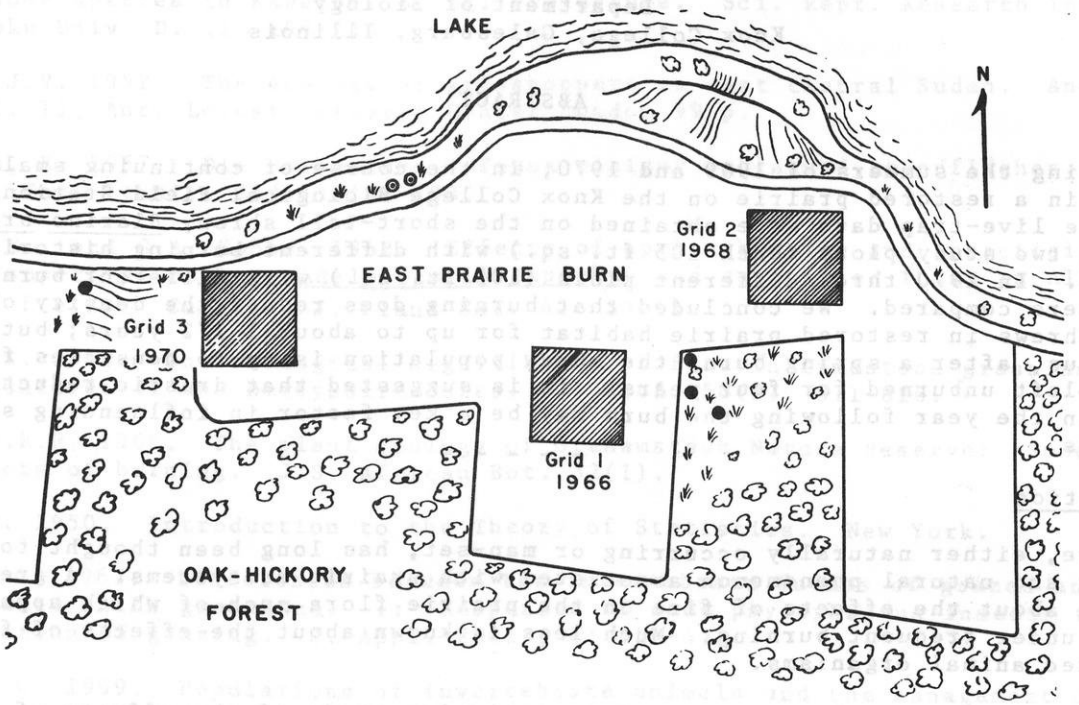


Table 1: Numbers of Individuals of Each Species, and Number of Captures for Each Species, During the Summers of 1969 and 1970, by Grid.

SPECIES	GRID AND YEAR									
	1('69)		2('69)		1('70)		2('70)		3('70)	
Blarina brevicauda	19	134	14	65	34	90	30	87	9	24
Microtus pennsylvanicus	8	19	18	40	1	1	0	0	1	1
Peromyscus leucopus	7	19	11	44	0	0	5	10	12	39
Peromyscus maniculatus	6	20	1	5	0	0	1	1	1	2
Zapus hudsonius	4	6	2	2	7	8	7	8	4	4
Reithrodontomys megalotis	2	3	4	6	0	0	0	0	0	0

Materials and Methods

The three plots used were each one-quarter acre, with a total of sixty-four livetraps per grid set at fifteen foot intervals. These traps remained set twenty-four hours a day, five days a week, and were checked every twelve hours.

Most authors have found high mortality rates in live-trapped Blarina brevicauda, even when traps were checked every four hours (Rood, 1958; New, 1959; and Doremus, 1964). Our trap mortalities were never more than 20% compared to the 35% found by Rood and the 40% by Doremus.

Each trap was placed under a nest of dead grass to protect any animals caught during the day from being overheated in the metal traps.

During the first week of both summers the grids were pre-baited. This was done by locking all the traps open and leaving a large handful of sunflower seeds in each. Sunflower seeds seem to be an effective bait for mice and shrews, being clean and easy to handle. Blarina respond well to sunflower seed-baited traps, consuming both seeds and insects which frequently enter the traps.

For this project two types of livetraps were used. One was the aluminim Longworth trap, composed of a 1-1/2 x 2 x 4 inch runway piece containing the triggering device and door, and a 3 x 1 - 3/4 x 4 inch nest box. The second type was the galvanized metal Sherman trap; a rectangular trap measuring 2 x 2-1/2 x 5 inches. These two types were alternately spaced in a symmetrical pattern throughout all grids to eliminate the possibility of trap style influence in one particular area.

The grids were checked every twelve hours, just after dawn and just before sunset. Each animal was toe-clipped and examined for sex, reproductive condition, weight, location, trap type, and time of day. Data were recorded on IBM mark-sense cards which could later be handled on an IBM 1130 computer.

To determine population densities, the average-distance-between-successive-captures method was used. This method is described by Schramm (1970).

Observations

In the summer of 1969, Grids 1 and 2 were studied. In the summer of 1970, all three grids were studied. There were 2,560 trap-nights in 1969 with 363 captures yielding 14.2 captures per 100 trap-nights. In 1970, with 4,143 trap-nights, there were 276 captures yielding 6.7 captures per 100 trap-nights; a considerable decrease. The trap-nights were equally divided between the separate grids.

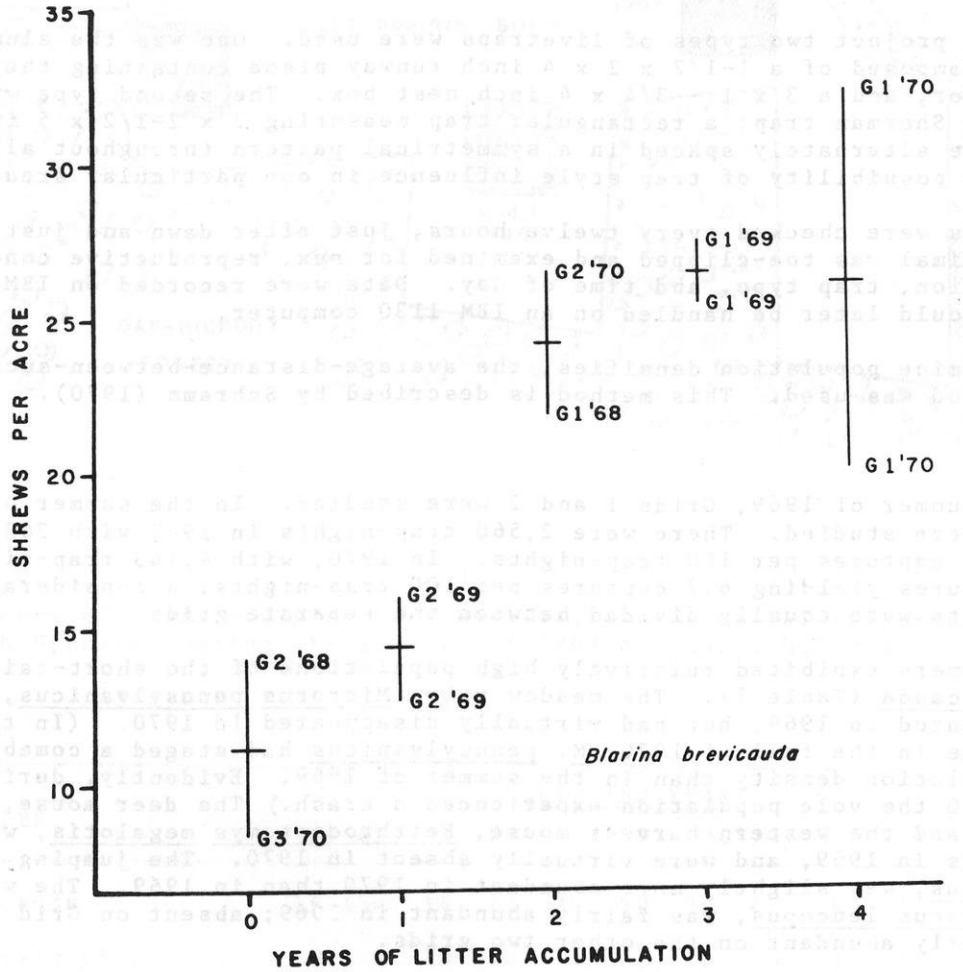
Both summers exhibited relatively high populations of the short-tailed shrew, Blarina brevicauda (Table 1). The meadow vole, Microtus pennsylvanicus, was moderately represented in 1969, but had virtually disappeared in 1970. (In the continuing study done in the fall of 1970, M. pennsylvanicus had staged a comeback, with a higher population density than in the summer of 1969. Evidently, during the summer of 1970 the vole population experienced a crash.) The deer mouse, Peromyscus maniculatus, and the western harvest mouse, Reithrodontomys megalotis, were found in low numbers in 1969, and were virtually absent in 1970. The jumping mouse, Zapus hudsonius, was slightly more abundant in 1970 than in 1969. The white-footed mouse, Peromyscus leucopus, was fairly abundant in 1969; absent on Grid 1 in 1970, but still fairly abundant on the other two grids.

The population density of Blarina is shown for each grid for both summers in Table 2. Summers were divided in half to indicate density changes. The densities increased slightly on all grids during both summers, with the least amount of change occurring on Grid 3 in 1970. The shrew density of Grid 2, two years after burning, during the first half of 1970, was 23.3 shrews per acre, and is very close to Schramm's 21.9 per acre, determined for Grid 1 two years after it was burned. His data were based on captures made during the early part of July in 1968, the same time interval used for the first half of the summer in 1970.

Because of small sample size, tests for significance are difficult to apply to the data, but certain trends are clearly indicates as can be seen in Figure II. The minimum and maximum density (including Schramm's data from 1968) are shown for each year of litter accumulation. The mean density for each period is graphed, showing the population growth curve.

FIGURE II

Short-tailed Shrews Per Acre Plotted Against Year of Litter Accumulation After a Fire. Vertical Lines Indicate Maximum and Minimum Range of Density Observed and Horizontal Lines Indicate Mean Densities. Grid Number and Year are Indicated for Maximum and Minimum Values.



Discussion

Schramm (1970) suggested that Blarina greatly prefer areas of accumulated litter. The data given here support that hypothesis. He further suggested that this litter preference may be due to the fossorial nature of Blarina, in that litter provides protection and a medium for forming surface runways. During the summers of 1969 and 1970 Blarina were observed to burrow beneath the litter almost immediately upon being released.

An additional reason for litter preference may have to do with the diet of Blarina. Whitaker and Ferraro (1963) found that earthworms, slugs and snails comprised 60% of the contents of the 221 Blarina stomachs studied. These food species tend to be most plentiful in moist areas; a micro-condition provided by heavily littered areas. Since fire destroys litter, the preferred habitat of the short-tailed shrew is also destroyed. Litter takes time to accumulate. From Figure II one can see that after one year of litter accumulation the density of Blarina is not much greater than it is for a newly burned area. The population density did increase, however, throughout the summer, reaching a mean density of 14.8 per acre. After two years of litter accumulation, the growth curve has begun to level off, having a mean density of 24.2 per acre. The mean for three years of accumulation is 26.5, and for four years it is down slightly to 26.2 per acre. Note that the last two mean densities are reached by the end of the summer in the area with two years of accumulated litter. Thus, as far as Blarina brevicauda is concerned, burning a prairie every three years, allowing two full years of litter accumulation plus one summer, would permit the population densities to advance to near climax levels.

As Table 1 indicates, during the summer of 1970 there were no Reithrodontomys, only two Microtus, and only two P. maniculatus. These three species are considered native to the prairies, and are therefore affected by the prairie burning. In the seven-acre restored prairie at the Knox College Field Station, Grid 1 has not been burned since 1966, and Grid 2 has not been burned since 1968. But the remainder of the prairie has been burned at least every other year, and portions have been burned every year since 1966. Although the low numbers of M. pennsylvanicus in 1970 may possibly be explained as a crash of a microtine cycle, no such explanation exists for Reithrodontomys or P. maniculatus. Furthermore, the prairie vole, M. ochragaster, mentioned by Schramm (1970) as being quite plentiful in 1966, has been captured so rarely since then that it, too, seems to be nearly absent. It is difficult to explain the continuing low numbers of this vole and these other species, but one possible explanation is that the intensive burning schedule the small semi-isolated east prairie has been subjected to may be a major influencing factor in the reduction and in some cases the near elimination of these small mammal species.

P. leucopus seems to thrive in more recently burned areas. If population densities were plotted for P. leucopus as in Figure 3, the resulting curve would be very nearly the mirror image of the Blarina curve, with the greatest density in an area with zero years of litter accumulation, and the lowest density in an area with four years of accumulated litter. When released after processing, P. leucopus have always stayed above the litter, and it seems reasonable to conclude that for reasons of locomotion they prefer unlittered areas.

Schramm (1970) suggested the Zapus prefer unlittered areas, giving locomotive ease as the reason. Since Zapus have a much greater home range than any other small mammal we were studying, the density of the Zapus population could not be calculated. If one considers the entire restored prairie, however, one can see from Table 1 that the numbers of Zapus increased between 1969 and 1970. All of the restored prairie was burned in the spring of 1970 except for Grids 1 and 2, and a small boundary strip around them. Although an accurate calculation of their population density is not possible in this study, the data do not discount Schramm's hypothesis, but seem to support it.

Conclusions

From this study we can conclude that burning has a temporary adverse effect on nearly all small mammal species found in the restored prairie. Exceptions are the white-footed mouse, P. leucopus, which invades from wooded areas, and possibly the jumping mouse, Zapus hudsonius. It is evident that the population density of the short-tailed shrew, Blarina brevicauda, is substantially reduced the summer following a spring burn, taking two full years, plus one growing season, for the population to recover to the maximum density.

The probable reasons for the reduction of the shrew population are lack of cover and food, both the result of the fire.

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Table 2: Population Densities of Blarina brevicauda per Acre. Summers were Divided in Half to Help Indicate Density Changes.

	Male	Female	Total
Grid 1 1969			
First half	17.5	8.0	25.5
Second half	18.2	9.3	27.5
Grid 2 1969			
First half	8.0	4.8	12.8
Second half	11.2	4.8	16.0
Grid 1 1970			
First half	11.3	8.8	20.1
Second half	21.2	11.2	32.4
Grid 2 1970			
First half	17.0	3.7	23.3+
Second half	24.1	2.5	26.6
Grid 3 1970			
First half	7.1	1.3	8.4
Second half	8.5	0.0	8.5

+There were a few individuals for which sex was not determined, which were included in the total population density.

SOME ASPECTS OF SMALL MAMMAL ECOLOGY IN A KANSAS REMNANT PRAIRIE

By

Eugene D. Fleharty

Biology Department, Fort Hays Kansas State College
Hays, Kansas

ABSTRACT

The four most numerous small mammal species (Sigmodon hispidus, Peromyscus maniculatus, Reithrodontomys megalotis, and Microtus ochrogaster) were studied by live-trapping from April 1965 through February 1969. Sigmodon and Peromyscus populations generally oscillated from high densities in the fall and early winter to low densities in the spring and early summer. Microtus densities peaked in spring and early summer and attained a low point in the fall and winter while Reithrodontomys attained highest trappable densities in the winter and spring with a low in the fall. All species underwent a 85-95% turnover in six months.

The highest ecological densities in animals per acre per favored habitat attained were 26.5 (Sigmodon), 18.2 (Peromyscus), 9.6 (Reithrodontomys), and 24.7 (Microtus). Exclusive boundary strip male home ranges averaged larger for Sigmodon and Peromyscus but smaller for Reithrodontomys and Microtus. However, based on greatest distance traveled males of all species tended to be more nomadic than females.

Sigmodon preferred habitats with a dense undergrowth and protective overstory as found primarily in the Andropogon gerardi/Kochia scoparia/Helianthus annuus community. Peromyscus preferred tall to midheight grass areas found in the Andropogon gerardi and A. gerardi/A. scoparius/B curtipendula community. Microtus preferred areas of dense ground cover found in the Buchloe dactyloides/B. curtipendula/Sporobolus asper, A. gerardi, and A. gerardi/A. scoparius/B. curtipendula communities and generally exhibited a negative preference for communities preferred by Sigmodon.

Vegetational clipping remains, resulting from Sigmodon hispidus activity, were collected and analyzed over a one year period. Sigmodon clipped 315.05 kg of vegetation on the study area (dry weight), with energy content of 136.4 x 10^4kcal. Grasses (mainly Andropogon gerardi, A. scoparius, and Bouteloua curtipendula) accounted for 54% of the vegetation clipped, Ambrosia psilostachya and Kochia scoparia 40%, and Helianthus annus 6%. Seventy-two percent of the clippings occurred in the fall (September - November).

The amount of clipped material/rat/month varied from zero in May to 1.3 kg in October. The amount of clipped material may not be solely dependent on a high Sigmodon density or activity, but possibly also on the condition of the vegetation and nest building activities of the rat. Of the net primary production in this area during the study period. 0.4% was clipped by Sigmodon.

Introduction

A live-trap, mark and release study was conducted from April 1965 through February 1969 on the same general area as that described by Dr. Hulett (see following paper). Sherman live traps placed in a grid at 50 foot intervals were run morning and evening for the first two weeks of each month with two omissions, thus giving data for 47 months.

Of the 12 species of small mammals trapped the cotton rat, Sigmodon hispidus; the deer mouse, Peromyscus maniculatus; the western harvest mouse, Reithrodontomys megalotis; and the prairie vole, Microtus ochrogaster, were the most common on the 13.77 acre study area.

I wish gratefully to acknowledge two graduate students, Yaroslaw Petryszyn and Michael A. Mares, who contributed a major portion of the data concerning Sigmodon hispidus.

Table 1: Vegetative Communities of The Study Plot

O = October
J = June
Y = July
S = September
A = August

Habitat No.	Dominant Species	Associated Species	Range of Mulch Depth (cm)	Range of Vegetation Height (cm)
1	Andropogon gerardi/ Andropogon scoparius/ Bouteloua curtipendula	Sporobolus asper, Sorghastrum nutans	3.2(O)- 4.2(J)	23.6(J)- 48.0(S)
2	Andropogon gerardi	---	7.2(O)- 8.6(J)	31.5(J)- 68.7(S)
3	Buchloe dactyloides/ Bouteloua curtipendula/ Sporobolus asper hookerii	Bouteloua gracilis, Agropyron smithii	2.8(O)- 3.8(J)	23.6(J)- 44.1(A)
4	Andropogon gerardi/ Kochia Scoparia/ Helianthus annuus	Ambrosia psilostachya, Rhus toxicodendron, Panicum virgatum, Chenopodium album Carex sp.	4.8(J)- 5.9(Y)	34.6(J)- 89.9(S)
5	Buchloe dactyloides/ Bouteloua curtipendula/ Sporobolus asper	Bouteloua gracilis, Agropyron smithii, Ambrosia psilostachya	2.2(O)- 4.5(J)	24.4(J)- 46.6(A)
6	Andropogon scoparius/ Andropogon gerardi/ Bouteloua curtipendula	Schrankia uncinata, Psoralea tenuiflora, Aster oblongifolius	4.4(J)- 5.4(Y)	23.6(J)- 48.0(S)

Table 2: Average Seasonal Ecological Densities in Number per Acre. See Table 1 for Dominant Plant Species Within the Habitats.

SPECIES	SEASON	HABITAT NUMBER					
		1	2	3	4	5	6
Sigmodon hispidus	Spring	0.4	3.7	4.7	3.8	4.8	0.8
	Summer	0.7	4.5	4.5	8.1	1.0	0.5
	Fall	1.7	11.7	8.0	13.9	2.9	1.3
	Winter	0.6	5.9	5.0	8.1	3.1	0.7
Microtus ochrogaster	Spring	1.5	3.0	7.3	1.5	1.7	1.6
	Summer	0.5	2.5	0.4	0.4	0.6	1.4
	Fall	1.0	1.0	0.7	0.6	0.9	0.6
	Winter	1.4	1.9	4.7	0.5	0.6	0.3
Peromyscus maniculatus	Spring	3.7	4.7	2.6	1.6	1.7	3.5
	Summer	2.9	2.8	2.6	1.6	2.2	2.2
	Fall	5.7	7.9	4.7	3.1	2.1	3.6
	Winter	6.8	6.7	2.8	3.5	2.0	3.9
Reithrodontomys megalotis	Spring	2.5	3.1	3.7	3.3	4.5	4.8
	Summer	2.6	3.3	3.0	2.5	2.5	3.0
	Fall	1.3	1.2	1.7	0.9	1.9	1.5
	Winter	1.8	3.2	2.7	3.3	5.4	3.4

Habitat Preference

Six habitats were included within the area sampled (Table 1). Based on the average catch per trap, Sigmodon preferred habitat number 4 in the summer, fall, and winter, and number 5 in the spring, whereas Microtus exhibited a preference for habitat number 3 in winter and spring, 2 in the summer and 1 in the fall. Peromyscus preferred habitats 1 and 2 in the fall, winter and spring and 1 and 3 in the summer, and Reithrodontomys preferred habitat 5 in the fall and winter and 5 and 6 in the spring and 3 in the summer.

Crude Densities

When monthly data were pooled to show seasonal values for the entire study area four distinct peaks generally occurring in the fall were evident for Sigmodon (Figure I). Microtus attained its maximum population in the spring and summer months at the time when Sigmodon populations were at a low or were decreasing. It has been suggested that there is considerable interspecific competition occurring between these two species (Svihla 1929, Meyer and Meyer 1944, Calhoun 1945, Martin 1956, 1969; Fleharty and Olson 1969) and the arrangement of peaks and valleys is certainly suggestive. The competition, I feel, is one encompassing the "time" and "place" niches rather than the "food" niche. Both species are diurnal and tend to occupy many of the same habitats. Although the two species utilize many of the same foot items (Fleharty and Olson 1969), I have found little evidence that food items are limiting to either species.

Peromyscus peaks in fall and winter with following lows in spring and summer whereas Reithrodontomys has a peak in winter and spring and lows are obtained in the fall (Figure II). Fitch (1958) attributes this low to the onset of seeds during these months which is the natural food of this species and therefore the population in effect becomes less trappable. However, Peromyscus also rely heavily on seeds as a food source and nevertheless attain their highest numbers in the fall. Perhaps there is some element of interspecific competition here as well. This has been suggested for related species Peromyscus gossipinus and Reithrodontomys humilis (Packard 1968).

Ecological Densities

Seasonal ecological densities were obtained by pooling monthly data into seasons and then averaging the seasonal values for the 47 month study period (Table 2). Ecological density as used here is in reality a habitat utilization figure as the figure was derived by multiplying the percent of the total captures occurring in a particular habitat by the total density recorded during each month. Care was taken in examining the data so that trap addicts would not bias my interpretations.

The highest ecological de_ties attained for any one month in numbers per acre during the entire study was 26 for Sigmodon, 18 for Peromyscus, 10 for Reithrodontomys, and 25 for Microtus.

Population Turnover

Pooling data for the entire study period, all species exhibit a rapid turnover in population numbers (Figure III). Most populations trapped and marked any one month are reduced by 70% after one month from the original capture and continued to be reduced until less than 5% of the original population remains after 11 months. Populations of Peromyscus did not turn over as rapidly as the other species studied with 45% of the originally marked population remaining the first month after marking. Microtus seemingly had the most rapid turnover with only 23% remaining in the first month after marking.

Greatest Distance Travelled

Exclusive boundary-strip home ranges averaged larger for the males of Peromyscus and Sigmodon than for females. When all seasons were lumped home ranges of the males averaged smaller, although not significantly so, than the females for Reithrodontomys and Microtus. Sample sizes were small for Reithrodontomys and Microtus and may have given an inadequate picture of the true relationships (Table 3).

In terms of greatest distance traveled the males of all species tended to be more mobile than the females with Peromyscus males being the most mobile of all species studied and female Microtus the least mobile (Table 4).

Vegetational Clippings

Recent trends in ecological studies have been toward energy relationships and nutrient cycling within an ecosystem. Researchers have investigated and elaborated on many phases of the energy flow within these systems. However, a neglected area is the amount of net primary productivity which is added to the fresh mulch compartment through the activities of certain rodents as they forage for food and gather nesting materials.

The cotton rat, Sigmodon hispidus, is an example of a primary consumer that clips vegetation during the course of foraging for food and probably in collecting nesting material. The material not utilized remains in the form of piles or stacks of clipped segments.

A total of 390 clipped materials from all communities and seasons were burned in an oxygen bomb calorimeter for energy analysis.

Calculating values for the entire study area, Sigmodon clippings left in piles amounted to 315.1 kg dry weight for the year February 1968-- January 1969. The energy contained in these clipped stacks was 136.1×10^4 kcal. This is a minimal figure because scattered individual clippings along runways were largely ignored.

The collected clipped material was divided into three major groups: (1) grasses; (2) Ambrosia/Kochia, which were treated as one; and (3) Helianthus. On this basis grasses comprised 54%, Ambrosia Kochia 40%, and Helianthus 6% of the annual amount found in clipped piles. These percentages may be used in referring to both dry weight and energy therein contained as percentages between these two values varied less than 1%.

Communities 2 and 4 accounted for 70% of the vegetational clippings. Community 1 comprised 13%, 3--11.5%, 5--5.5% and 6--0.6%. The monthly caloric value of the clippings and the relative amounts of the vegetation comprising the clipped piles is shown in Table 5.

The peak energy value of clipped material was obtained in October with approximately 450,000 kcal and the least was in May when no clipped piles were found. This is probably because the animals are utilizing the freshly emergent tender shoots of vegetation. In the spring all clippings were composed of grass. Grasses increased in amount in late summer and fall until there was 100% grass utilization in January. The increase in grass usage in August and September is probably due to the increased usage of Panicum capillare which had seed heads at this time and which accounted for 33% of the grass clippings in September.

The peak in Sigmodon population occurred in September with 81 rats present while in February 1969 no Sigmodon were trapped. The amount clipped is positively correlated with the population estimate ($r = 0.718$, $p = 0.01$). The amount of clipped material per rat per month varied from zero in May to 1.3 kg in October.

Taking primary net production figures determined by Brock (1968), using the short term harvest method, and applying energy values herein obtained, a total of $34,860 \times 10^4$ kcal/year were produced on the study area. Adding the amount estimated to have been found in clipped piles (i.e. 136.1×10^4), the total primary net production would be $34,966.1 \times 10^4$ kcal/year. Thus the Sigmodon hispidus population for the year removed 0.4% of the primary net production and left it in the form of clipped piles. This value (0.4%) might be considered high as the net primary production is still minimal because of the activities of other heterotrophes. However, not all clipped material was found as stacks and thus collected, so the value is probably minimal.

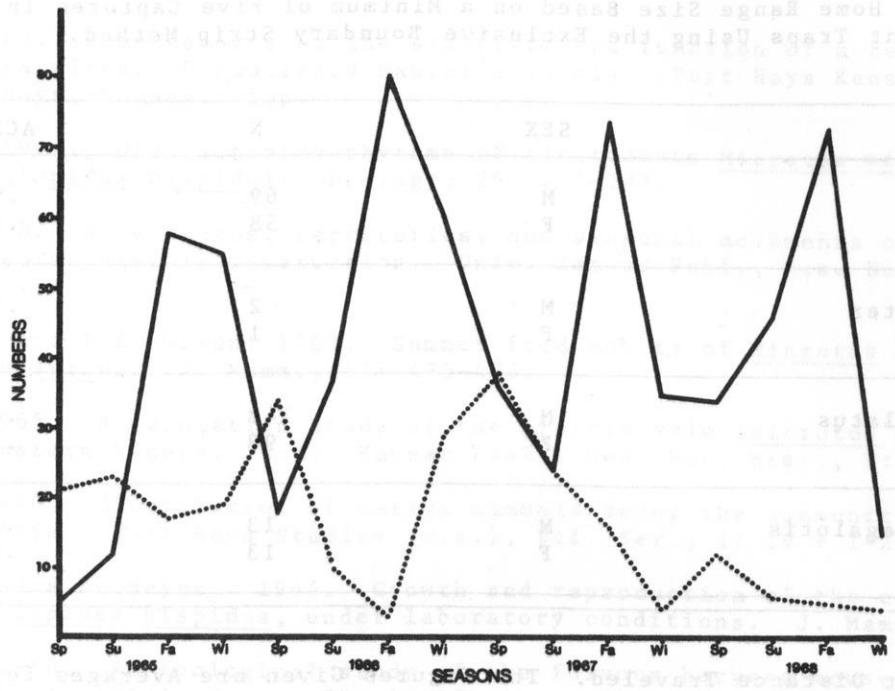

FIGURE I

Seasonal Crude Population Densities of Sigmodon hispidus (solid line) and Microtus ochrogaster (dotted line).

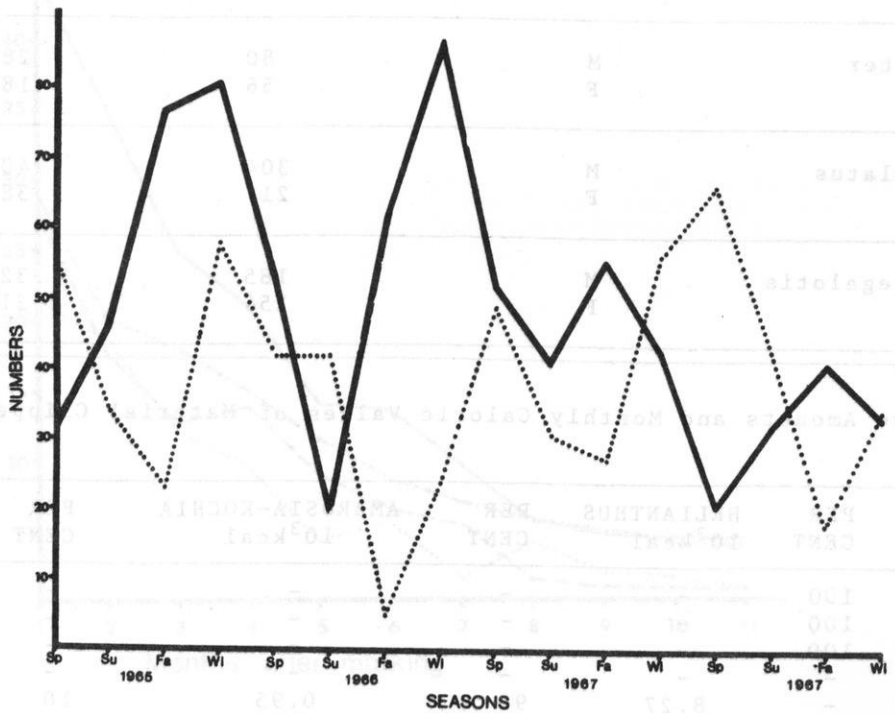

FIGURE II

Seasonal Crude Population Densities of Peromyscus maniculatus (solid line) and Reithrodontomys megalotis (dotted line).

Table 3: Average Home Range Size Based on a Minimum of Five Captures in Five Different Traps Using the Exclusive Boundary Strip Method.

SPECIES	SEX	N	ACRES
Sigmodon hispidus	M	69	.969
	F	58	.543
Microtus ochrogaster	M	2	.564
	F	1	.580
Peromyscus maniculatus	M	148	.827
	F	98	.732
Reithrodontomys megalotis	M	13	.690
	F	13	.694

Table 4: Greatest Distance Traveled. The Figures Given are Averages for All Seasons.

SPECIES	SEX	N	FEET
Sigmodon hispidus	M	362	330.0
	F	253	250.9
Microtus ochrogaster	M	80	285.3
	F	56	187.3
Peromyscus maniculatus	M	304	407.1
	F	217	385.5
Reithrodontomys megalotis	M	185	321.8
	F	154	313.6

Table 5: Relative Amounts and Monthly Caloric Values of Material Clipped by Sigmodon.

MONTHS	GRASSES 10^3kcal	PER CENT	HELIANTHUS 10^3kcal	PER CENT	AMBROSIA-KOCHIA 10^3kcal	PER CENT
Feb.	68.05	100	-	-	-	-
March	75.95	100	-	-	-	-
April	36.12	100	-	-	-	-
May	-	-	-	-	-	-
June	-	-	8.27	90	0.95	10
July	0.62	11	1.22	22	3.67	67
Aug.	37.21	43	4.81	5	45.49	52
Sept.	133.45	45	35.85	12	127.63	43
Oct.	154.44	34	13.94	3	284.38	63
Nov.	132.40	63	10.46	5	68.19	32
Dec.	59.40	81	3.16	4	10.56	15
Jan.	16.54	100	-	-	-	-

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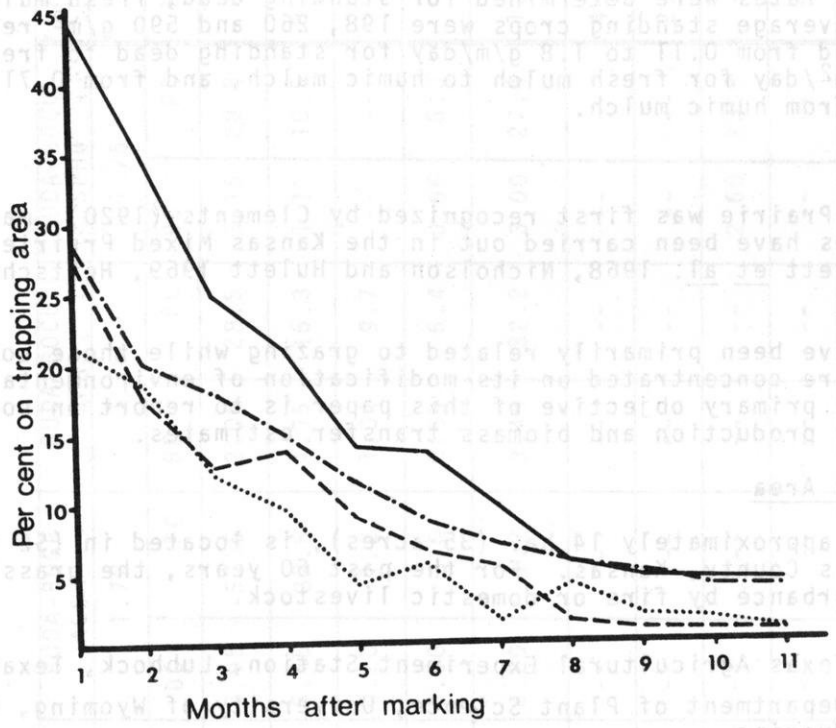

FIGURE III

Percent of Sigmodon hispidus (---), Microtus ochrogaster (···), Reitnrodontomys megaiotis (-·-·), and Peromyscus maniculatus (_____) remaining on the study area each month after the original marking.

COMMUNITY STRUCTURE AND FUNCTION IN A REMNANT KANSAS PRAIRIE

By

G.K. Hulett, J.H. Brock[1] and J.E. Lester[2]

Division of Biological Sciences and Agriculture
Fort Hays Kansas State College
Hays, Kansas

ABSTRACT

The vegetation structure and soils in a 14 ha. remnant Mixed Prairie grassland near Hays, Kansas were studied during 1967-1968. Part of the old Fort Hays Military Reservation, it has not been grazed, burned or mowed since about 1902.

Various portions of the prairie were dominated principally by Andropogon gerardi, Andropogon scoparius, Buchloe dactyloides, Bouteloua gracilis, Bouteloua curtipendula, Agropyron smithii and Sporobolus asper. The distribution and abundance of these grasses were controlled by soil factors, topographic position, underlying parent material and past history.

Four major soil types have developed in this grassland. These soils range from the fine textured non-calcareous Mento (supporting Buchloe dactyloides, Bouteloua gracilis and Agropyron smithii) through the shallow, immature calcareous Brownell (supporting Andropogon gerardi, Andropogon scoparius and Bouteloua curtipendula) to the alluvial-colluvial Armo and Roxbury (supporting Andropogon gerardi, Kochia scoparia and Helianthus annuus).

Net shoot production, estimated in the portion dominated by Andropogon gerardi, Andropogon scoparius and Bouteloua curtipendula, at 296 g/m^2; productivity rates ranged from a low of 1.5 g/m^2/day to a high of 2.7 g/m^2/day.

Biomass transfer rates were determined for standing dead, fresh mulch, and humic mulch, whose average standing crops were 198, 260 and 590 g/m^2 respectively. Transfer rates ranged from 0.11 to 1.8 g/m/day for standing dead to fresh mulch, from 0.29 to 2.0 g/m^2/day for fresh mulch to humic mulch, and from 0.71 to 2.1 g/m/day for losses from humic mulch.

Introduction

Since the Mixed Prairie was first recognized by Clements (1920), many structural ecology studies have been carried out in the Kansas Mixed Prairie, (Albertson 1937, Hulett et al. 1968, Nicholson and Hulett 1969, Heitschmidt et al. 1970).

These studies have been primarily related to grazing while those concerned with biomass structure concentrated on its modification of environmental factors (Hopkins 1954). The primary objective of this paper is to report on some preliminary net primary production and biomass transfer estimates.

Description of Study Area

The remnant, of approximately 14 ha. (35 acres), is located in (SE ¼ Sec. 1, T. 14S, R. 19W) Ellis County, Kansas. For the past 60 years, the grassland has been free from disturbance by fire or domestic livestock.

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[1]Present Address: Texas Agricultural Experiment Station, Lubbock, Texas.

[2]Present Address: Department of Plant Science, University of Wyoming, Laramie, Wyoming.

Table 1: Size, species dominants (PC) and basal cover (BC) on eight sectors in a remnant Kansas prairie.

SECTOR	BUDA-BOGR AGSM		BUDA-BOCU SPAS		BUDA-BOCU SPHO		ANGE-ANSC BOCU		ANGE-ANSC		ANGE		ANSC-ANGE BOCU		ANGE-KOSC HEAN	
ACRES	1.72		1.26		1.75		5.00		5.17		2.01		9.65		5.51	
DOMINANT SPECIES	BC	PC	BC	PC	BC	PC	BC	PC	BC	PC	BC	PC	BC	PC	BC	PC
Buchloe dactyloides	8.95	53.6	3.05	28.5	3.15	28.8	--	--	--	--	--	--	--	--	--	--
Bouteloua gracilis	5.45	32.6	1.75	16.3	1.15	10.5	0.75	1.6	--	--	--	--	--	--	--	--
Sporobolus asper	0.20	1.2	1.04	9.7	--	--	--	--	--	--	--	--	--	--	--	--
Agropyron smithii	0.60	3.6	0.69	6.4	0.66	6.0	--	--	--	--	--	--	--	--	0.05	0.6
Bouteloua curtipen-dula	0.20	1.2	3.45	32.2	3.00	27.4	1.57	16.9	0.20	2.2	--	--	3.25	18.1	--	--
Andropogon gerardi	--	--	--	--	--	--	4.12	44.2	4.45	63.4	6.85	96.5	3.92	50.4	4.27	50.7
Andropogon scoparius	--	--	--	--	--	--	2.13	22.8	2.00	28.1	--	--	5.15	28.6	--	--
Sporobolus hookeri	--	--	--	--	2.60	23.8	--	--	--	--	--	--	--	--	--	--
Kochia scoparia	--	--	--	--	--	--	--	--	--	--	--	--	--	--	2.86	33.9
Helianthus annuus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.30	3.4
Other species	1.55	7.8	0.73	6.9	0.37	3.5	1.28	14.5	0.20	5.0	0.25	3.5	0.79	02.9	1.09	11.4
TOTAL COVER	16.95	--	10.71	--	10.93	--	9.85	--	6.85	--	7.10	--	13.11	--	8.57	--

This remnant overlies strata of Cretaceous age, particularly materials of the Niobrara formation. The prominent stratum exposed belongs to Fort Hays limestone. A second parent material found in the study area is a post-Pleistocene deposit occurring as caps on the residual limestone. The area is characterized by a large central drainage bordered by steep and gentle slopes.

Annual precipitation averages 584 mm with about 75% falling as rain from April through September. In 1968, only 330 mm of precipitation were recorded during the growing season, approximately 127 mm under normal. In 1968, the frost-free period was 187 days.

Methods and Procedures

This study was begun in June, 1967 and continued through February, 1969. Nine subdivisions of the area, characterized by their dominant species, were mapped in the field and then transferred to aerial photographs. A small area dominated by poison ivy (Rhus toxicodendron) was deleted from further analysis. Basal cover and species composition were estimated using at least 50 one-meter transects in each sector. Five soil cores were taken to depths allowable by underlying strata in each sector and analyzed for selected soil characteristics.

In January, 1968, the sector dominated by Andropogon gerardi, A. scoparius and Bouteloua curtipendula was selected for intensive study of productivity and biomass transfer rates. At monthly intervals from January, 1968 to February, 1969, 30 randomly located 1/8m^2 quadrats were harvested in the community. The above-ground herbage was separated into four categories: green herbage, standing dead, fresh mulch, and humic mulch (Dyksterhuis and Schmutz 1947).

Results and Discussion

1. Description: Although structural aspects of all eight sectors were investigated (Table 1), only five will be discussed here. The Buchloe dactyloides-Bouteloua gracilis-Agropyron smithii (BUDA-BOGR-AGSM) community, first described by Albertson (1937), is characteristically dominated by short grasses. The presence of these drought-resistant species is attributed to the high clay content of the B_{2t} horizon (20-25 cm in depth; Table 2), which results in decreased water infiltration. The xeric soil condition is augmented by the southern exposure and upland position which increases evapo-transpiration rate. This BUDA-BOGR-AGSM (short grass) community is underlain by deep regosolic soils of the Mento series.

Moving down the slope is an Andropogon gerardi--Andropogon scoparius--Bouteloua curtipendula region (ANGE-ANSC-BOCU) on Brownell soils, where the productivity and biomass estimates were studied; refer to Tables 1 and 2.

Also present on upper slopes is a sector dominated by Andropogon scoparius, Andropogon gerardi, and Bouteloua curtipendula (ANSC-ANGE-BOCU). Hulett and Tomanek (1969) reported that the rocky, shallow soils underlying this community support diverse forb populations. Brownell, a regosolic soil, is the dominating series. These are shallow, A-C soils and often have "scabby" areas with no vegetation.

On lower slopes paralleling the major drainage is an Andropogon gerardi (ANGE) stand--extremely homogeneous in botanical composition--on an alluvial-colluvial regosolic soil of the Armo series. The Armo soil has less silt and more rock in the A_1 horizon than the Mento.

Traversing the study area, the major drainage system is dominated by Andropogon gerardi, Kochia scoparia, and Helianthus annuus, whose weedy structure deviates considerably from the lowland community of western Kansas described by Albertson (1937). Field observations of other ungrazed lowland communities indicate that weediness is a common aspect of such habitats, possibly a result of

Table 2: Selected soil characteristics of four soil types found in a remnant Kansas prairie.

SOIL TYPE	HORIZON	DEPTH (")	TEXTURE			% Rock	pH	% OM
			Sand	Silt	Clay			
MENTO	A_1	0-8.2	4.0	68.4	28.7	--	7.3	2.91
	B_{2T}	8.2-10	1.9	53.8	43.6	--		
	B_{2CA}	10.0-23.0	HEAVY SILTY CLAY LOAM			--		
ARMO	A_1	0-8	8.0	59.2	32.7	15.1	7.8	3.50
	AC	8-18.6	7.2	45.9	46.9	30.6		
	C_1	18.6-27	CLAY LOAM					
BROWNELL	A_1	0-6	9.5	64.3	26.3	19.4	7.7	3.70
	AC	6-12	12.3	48.1	39.6	57.1		
	C	12-18	GRAVELLY LOAM					
ROXBURY	A_{11}	0-10	2.9	59.3	37.6	--	7.6	3.96
	A_{12}	10-22	7.9	50.7	41.4	19.9		
	A_{13}	22-32	SILT LOAM					

Table 3: Green Biomass Standing Crop Estimates for an Andropogon gerardi-Andropogon scoparius-Bouteloua curtipendula community in a remnant Kansas prairie. May 1968 to October 1968.

PERIOD	INTERVAL DAYS	PEAK STANDING CROP (g/m^2)	POSITIVE BIOMASS GAIN	RATE (g/m^2/day)
May - June	31	45	45	1.5
June - July	31	95	50	1.6
July - August	28	170	75	2.7
August - Sept.*	32	130		
Sept. - Oct.*	30	65		
Growing Season**	187	296		1.6

* Positive Biomass change not detectable following peak standing crop.

** Estimated net shoot production based on peak standing crop + 73%.

drainage from surrounding grazed pastures or cultivated cropland. The upper end of this sector is irrigated by drainage from the pond. This lowland has homogeneous alluvial regosols, of the Roxbury series.

Soil and vegetation variability exists in some areas as a result of the old wagon trails that traverse the area from east to west--trails known as the Fort Downer road and alternates of the Fort Dodge and Santa Fe Trails (H.L. Legleiter, personal communication). Erosion along these old trails has caused some segregation of Andropogon scoparius into the shallow-soiled eroded ruts and Andropogon gerardi onto the ridges between the ruts.

2. Standing Crop Biomass: Odum (1960) considers that for maximum accuracy with the short-term harvest method, estimates of individual species' peak standing crop during the growing season must be obtained. However, other workers (Malone 1967; Hadley and Buccos 1967) have found that the community peak standing crop can give a statistically more reliable estimate of net primary production, particularly in areas where the production is distributed among a few species and where those species reach their peak growth at about the same time. In the ANGE-ANSC-BOCU sector chosen for study, the phenology of the major producers posed no special problem. Brock (1968) reported that the three dominant grasses and most of the less important species in the community attained peak standing crop near August 1.

The peak standing crop (170 g/m^2) for the growing season in the ANGE-ANSC-BOCU was reached in late July, 1968 (Table 3). Net gain in biomass between sample periods divided by the number of days in the sampling interval resulted in the estimated productivity rates. The peak standing crop values have not been corrected for any loss from the green herbage that occurred during the growing season and therefore are minimal estimates.

3. Biomass Transfers: Standing crop data (Table 4) allowed input and output rates to be calculated for various time intervals. Rates prior to and following the growing season (January to April; October to February) were detectable from the difference in standing crop from one date to another. During the growing season (April to October) direct difference calculation of transfer rates was not possible due to concurrent input from green herbage.

Contribution of green herbage to standing dead occur during the growing season, as portions of the plants die, and at the end of the growing season when all of the green biomass becomes standing dead. These inputs, plus the initial standing dead, minus the final standing dead equals the input to fresh mulch. This input divided by the number of days in the interval yields an input rate in g/m^2/day (Table 5).

4. Discussion: Golley (1965) stated that peak standing crop cannot be equated directly to net shoot production because of the input of green herbage into a standing dead state during the growing season, which he estimated at 73% of peak standing crop. Also consumption by small mammals must be considered, which we estimated at 1% of net shoot production. No correction was made for invertebrate consumption, likely a larger figure than for mammalian consumption.

When these two losses (input to standing dead, and mammalian consumption) are summed (126 g/m^2) and added to the community peak standing crop (170 g/m^2), a minimal net shoot production estimate of 296 g/m^2 is obtained. This figure compares well with the 320 g/m^2 reported by Weigert and Evans (1964) and the 390 g/m^2 of Harris (1966); but it is lower than the 609 reported by Golley (1965) and the 534 of Kelly (1969). However, considering variations in weather and phenology, physiognomy, geographic location and maturity of the communities reported on, these variations in net production are to be expected.

The productivity rates are of the same magnitude as those in the literature. Odum (1960) reported production rates in perennial grasslands as 2.2 g/m^2/day during spring and 1.5 g/m^2/day during summer. Hadley and Buccos (1965), working in an eastern North Dakota prairie, found biomass to accumulate at an average of 2.7 g/m^2/day, while in our study the average rate was 1.6 g/m^2/day. Harris (1966) and Kelly (1969) reported production rates of 2.4 g/m^2/day and 3.34 g/m^2/day respectively.

Table 4: Standing crop estimates for four biomass categories in an *Andropogon gerardi* - *Andropogon scoparius* *Bouteloua curtipendula* community in a remnant Kansas prairie. Values are in g/m^2. Values in parentheses are percentages of total biomass.

	SAMPLING DATE	STANDING DEAD	FRESH MULCH	HUMIC MULCH	GREEN HERBAGE	TOTAL BIOMASS
1968	January 29	254 (22)	300 (26)	605 (52)		1159
	February 29	260 (20	312 (24)	710 (55)		1282
	March 30	216 (22)	235 (24)	510 (53)		962
	April 30	244 (22)	248 (23)	602 (55)		1094
	May 30	184 (17)	266 (25)	566 (53)	45 (4)	1060
	June 30	159 (18)	170 (19)	462 (52)	95 (11)	886
	July 28	114 (10)	249 (22)	592 (53)	170 (15)	1123
	August 29	147 (13)	203 (18)	625 (57)	130 (12)	1106
	September 28	182 (15)	272 (23)	681 (57)	66 (6)	1201
	October 30	218 (22)	207 (21)	574 (58)		999
	December 2	213 (20)	266 (24)	610 (56)		1090
1969	February 4	180 (19)	217 (23)	538 (58)		934
	Average	198 (18)	247 (23)	591 (55)	42 (4)	1075

838 (78)

Table 5: Compartmental transfer rate estimates in an Andropogon gerardi - Andropogon scoparius - Bouteloua curtipendula community in a remnant Kansas prairie. Data are from January 1968 to February 1969. Standing crop values are g/m^2.

	INITIAL CONDITION	INPUT	FINAL CONDITION	TRANSFER TO NEXT COND.	TIME (DAYS)	TRANSFER $gm/m^2/day$
January to April						
Standing dead	254		244	10	92	0.11
Fresh mulch	300	10	248	62		0.67
Humic mulch	605	62	602	65[1]		0.71
April to October						
Standing dead	244	296[2]	218	322	184	1.80
Fresh mulch	248	322	207	363		2.00
Humic mulch	602	363	574	391[1]		2.10
October to February						
Standing dead	218		180	38	96	0.40
Fresh mulch	207	38	217	28		0.29
Humic mulch	574	28	538	64[1]		0.67

[1]Quantity disappearing

[2]Includes 126 gm contributed during growing season and 170 gm contributed at end of season.

The standing dead mean of 198 g/m^2 is similar to the 189 g/m^2 of Golley and Gentry (1966). The higher standing dead values prior to the 1968 growing season reflect standing dead produced in the 1967 growing season. The lower values after the 1968 growing season indicate the relatively low input to standing dead from green herbage during the dry 1968 season, accounting for only about 19% of the total aerial biomass in the ANGE-ANSC-BOCU community.

The rate of fall of standing dead compared well with rates reported by other workers. Over a four-year period Golley (1965) found losses from standing dead to range from 183 to 394 g/m^2/year. Standing dead losses in the ANGE-ANSC-BOCU community were estimated 369 g/m^2/year. Harris (1966) reported a transfer rate of 598 g/m^2/year with the highest of a high standing dead fall during the summer. Whether this reflects the heavier winter precipitation and warmer winter temperatures in the southeastern United States and their effect on standing dead fall is uncertain. Kelley (1969) determined the mean daily fall of Andropogon virginicus standing dead and found it to be 0.98 g/m^2. When the 369 g/m^2 annual input to fresh mulch is divided by the number of days in our study, the fall of standing dead is also 0.98 g/m^2/day.

Many workers studying biomass transfers divide the non-living community biomass into only two compartments: standing dead and litter. Hence, we summed both fresh and humic mulch categories in order to compare litter standing crops and litter transfer rates.

The average mulch level for the entire year was estimated at 838 g/m^2. This is considerably higher than the values reported on old fields by Odum (1960) (500 g/m^2), Golley (1965) (250 g/m^2), Harris (1966) (258 g/m^2) and Kelly (1969) (181 g/m^2). However, it is very similar to the 697 g/m^2 on excellent condition rangeland and the 1082 g/m^2 on a relict prairie in Texas reported by Dyksterhuis and Schmutz (1947). This finding supports the concept that with increasing community maturity, the total non-living biomass of the system increases. The importance of mulch on modifying the grassland environment in Kansas has been documented by Hopkins (1954).

The highest litter disappearance rate occurred during the summer (65 g/m^2/mo.) while the low was in the winter (21 g/m^2/mo.). An average litter decay rate of 43 g/m^2/mo. compares to figures reported by Harris (1966) and Kelly (1969) for an Andropogon virginicus old field. Harris (1966) found a summer litter decay rate of 76 g/m^2/mo. and a winter rate of 45 g/m^2/mo., the same pattern seen in our ANGE-ANSC-BOCU community, probably reflecting higher summer temperatures and greater microbiological activity (Kuranov 1961). Litter is the dominant biomass state in the ANGE-ANSC-BOCU community, making up an average 78% of the total biomass during the year (Table 4).

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GROWTH OF LIATRIS ASPERA IN PHOSPHORUS-DEFICIENT SOILS

By

M.L. Wuenscher and G.C. Gerloff

Forestry Department of Duke University
Chapel Hill, North Carolina

Institute of Plant Development and Botany Department
University of Wisconsin, Madison, Wisconsin

ABSTRACT

The absorption of P by blazing star (Liatris aspera Michx.), a native prairie composite, from an extremely P-deficient soil, and the importance of its corm in P storage and re-export were investigated. By the end of a growing season, a corm may contain enough P to support the entire shoot growth of the following season. Between blooming and the end of the growing season, P in the corm is replenished by a very rapid and efficient absorption from the soil. Storage of P in the corm seems an important factor in successful growth of blazing star in P deficient soils. The unusual efficiency of P absorption by its root system would be an additional factor contributing to the success of blazing star under P deficiency.

Introduction

Blazing star (Liatris aspera) is one of several native plant species which grow successfully in a soil extremely deficient in available P as indicated by both chemical and biological assays (Wuenscher, 1970). This soil, which tests only 4 to 10 pounds of available P per acre, is located on Buena Vista Marsh, a drained marsh in the sand plains of central Wisconsin studied by Zedler and Zedler (1969). Soil and plant materials used in the study were obtained from an area of the marsh known as the Krueger stand (SE1/4, Sec. 10, T21N, R7E).

Blazing star grows from a perennial underground corm which may produce either a non-flowering basal rosette of leaves or from one to many erect, flowering stalks. The growth of blazing star in P deficient areas is of particular interest because the rapid growth of the large, erect flowering stalks would seem to require greater amounts of P, and other essential elements, than could be absorbed from a low-fertility environment. This suggests that the corm provides a large part of the P required for flower stalk development. In a preliminary greenhouse experiment, it was observed that blazing star plants grown from corms in unfertilized Krueger soil did obtain only 25 per cent of their total P from the soil.

In this investigation, the uptake of P by blazing star plants throughout the growing season, the distribution of P in the plants, and the role of the corm in P storage and re-export were studied by P analysis of plants collected from the field at several stages of growth.

Methods

Phosphorus contents of blazing star corms and flowering stalks from the Krueger stand were determined. Twenty erect flowering stalks were collected on July 4, August 12, and October 7, 1968. Ten were from plants having one flowering stalk and ten were from plants having two to four flowering stalks. Flowering stalks were separated into leaves, stems, and floral parts. Corms of plants with one flowering stalk, of plants with two to three flowering stalks, and of plants with three to four flowering stalks were collected on October 3, 1967, August 12, 1968, and October 7, 1968. Corms of each type, leaves, stems, or floral parts were combined into one sample for dry weight and per cent P determinations. Tissue was ground in a Wiley mill to pass a 40 mesh screen and duplicates of each sample were dry ashed and analyzed for total P by a vanadomolybdate yellow color method (Jackson, 1958).

Results

As shown in Table 1, blazing star flowering stalks increased in total P content by about 3.5 times between the July and October samplings of 1968. This increase even continued after the plants had bloomed in mid-August. The P content of the leaves varied only slightly, but the content of stems and especially the floral parts increased greatly. The P concentration of leaves declined from 0.11 per cent in July to 0.08 per cent in October; that of stems declined from 0.08 per cent to 0.04 per cent. The P concentration of floral parts was near 0.22 per cent in both July and October but dropped to 0.18 per cent in mid-August at the time of bloom.

Between the end of the 1967 growing season and the mid-August bloom of 1968, the P content of one-stalk corms decreased from 6.08 to 1.11 mg and that of two to three stalk corms from 6.88 to 1.59 mg. The corms then increased greatly in P content, as much as 8 mg, between mid-August and the end of the 1968 growing season. Although there was a slight increase in corm weight between August and October, most of the change in total P content was associated with changes in P concentrations in the corms. For example, corms collected in October, 1967, averaged 0.12 per cent P. A sample of corms from plants both with basal rosettes of leaves and erect stalks collected on June 15, 1968, had 0.07 per cent P. By August 12, flowering corms averaged only 0.04 per cent P,yet by October 7 concentrations had increased to 0.16 per cent.

Discussion

Beadle (1966) suggested that the possession of an underground organ and the perennial habit would be advantageous to plants growing under conditions of low nutrient supply. In agreement with this viewpoint, the corm and perennial habit of blazing star appear to be factors involved in its successful growth on the P-deficient soil of Buena Vista Marsh. At the end of the growing season, most corms contained from 70 to 100 per cent as much P as did shoots of the same plant at the time of maximum P content. The largest corms collected, which had three or four flowering stems, contained 130 per cent as much P as their shoots. The decrease in amount and concentration of P in corms between fall and early summer and the time of bloom suggests that corm P is exported to the shoot for use during its rapid development.

Blazing star also absorbed P readily from the P-deficient Krueger soil. For example, plants with one flowering stalk contained over 8 mg more P in the stem and corm on October 7 than on August 12. Plants with an average of 2 1/2 flowering stalks contained about 16 mg more P. The increase in corm P concentration from 0.04 per cent to 0.16 per cent during this same period also indicated a rapid absorption of P. When blazing star was grown from corms in two-liter pots of unfertilized Krueger soil in the greenhouse, each plant absorbed 1.8 mg of P from the soil (Wuenscher, 1970). Marglobe tomatoes grown from seed under the same conditions were extremely stunted, showed symptoms of severe P deficiency, and contained only 0.065 mg of P per shoot. Under conditions of P deficiency in a sand-culture, nutrient experiment (Wuenscher, 1970), Kentucky bluegrass (Poa pratensis L.), little bluestem (Andropogon scoparius Michx.), and blazing star grown from seed collected from the Krueger area absorbed 1.41, 1.25, and 5.23 mg P respectively per gram of oven-dry roots. These data suggest that roots of blazing star have unusual capacity to absorb P under conditions of low soil availability.

The absence of P re-export from the leaves at the end of the growing season when large amounts were being accumulated in seeds and corms was unexpected. The continued absorption of P by plants late in their growth cycle also is unusual (Dean and Fried, 1953).

The corm of blazing star, therefore, stores sufficient P to support shoot growth of the following season. The plant can bloom independently of the external P supply. This P is exported to shoots during spring and summer through the time of bloom. Corm P is then replenished by the end of the growing season by a rapid and very efficient absorption of soil P. These physiological mechanisms seem important in enabling blazing star to survive, compete successfully with other plants, and rapidly produce large, flowering stalks under conditions of low P supply.

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Table I. Mean P contents of blazing star flowering stalks and corms collected at intervals during the growing season.

	mg P in plant part on*			
Plant Part	10/3/67	7/4/68	8/12/68	10/7/68
Flowering stalk	--	1.76(20)	3.27(20)	6.10(20)
leaves		1.02	0.93	0.90
stem		0.50	0.62	1.08
floral		0.24	1.72	4.12
Corm				
with 1 stalk	6.08(6)	--	1.11(10)	6.94(9)
with 2 to 3 stalks	6.88(4)	--	1.59(4)	10.54(6)
with 3 to 4 stalks	21.44(2)	--	--	28.14(3)

* The number of stalks or corms collected is given in parentheses.

NODULATION AND SYMBIOTIC NITROGEN FIXATION BY PRAIRIE LEGUMES

By

Joseph C. Burton

Research Department, The Nitragin Co., Inc.
3101 West Custer Avenue, Milwaukee, Wis.

ABSTRACT

The indigenous flora of the Midwest Prairies consists of a great number of leguminous plant species capable of working symbiotically with special bacteria called "rhizobia" in nodules on their roots and gathering free atmospheric nitrogen for their own growth and possibly for their non-leguminous associates which may otherwise be deprived of nitrogen.

The occurrences of various prairie legumes and their nitrogen-fixing abilities will be demonstrated in color slides. These include species of Astragalus, Baptisia, Cassia, Desmodium, Lespedeza, Petalostemum, Strophostyles, Tephrosia, and Vicia. Effective and ineffective nodulation and methods of sending nodules to the laboratory for isolation purposes will be reviewed.

The final part of the discussion concerns artificial inoculation of prairie legume seeds--the inoculants available and easy methods to effectively inoculate leguminous seeds.

Introduction

Nature endowed leguminous plants with a perhaps unique system of obtaining nitrogen. By working with special bacteria (rhizobia) in nodules on their roots, they can utilize the gaseous nitrogen of the atmosphere. This built-in nitrogen source makes legume growth independent of the soil supply. Perhaps because of this fact, leguminous plants were apparently well represented in the original prairie ecosystem (Fasset, 1939; Turner, 1959; Anderson, 1961).

In some instances, effectively nodulated leguminous species also provide nitrogen for companion grasses as a result of intermingling of root systems. However, root nodules provided no protection against the plow or shovel, and the leguminous species were lost along with other biotic constituents when the prairies were uprooted for other purposes.

Much interest has developed recently in restoring some of our tall-grass prairies to their natural beauty and resourcefulness as habitats for bird and animal life. However, as several workers (Schulenberg, Schramm, Bland, and others) pointed out in our first symposium, restoration is a long and arduous task. The prairie remnants are often the only source of propagating stock of adapted indigenous species, and plants or cuttings must be removed carefully and sparingly to avoid further destruction. Seeds can be collected from native plants but establishment is difficult because the environment is often very hostile to young seedlings. Special techniques of plant culture and prairie restoration are being developed (Bland, 1968; Kilburn, 1968; Landers et al, 1968; Ode, 1969; Schulenberg, 1968; Vocelka, 1968). Fortunately, many of the leguminous species in the biota of the native prairie produce seeds which can be collected and planted in new areas.

The ability of leguminous species to grow and compete with weeds and other natural enemies in the ecosystem often depends upon the presence of effective nodules on their roots which give them a nitrogen supply not available to other plants. But often the proper nodule bacteria are not present in our soils. To insure effective nodulation of new legume seedlings, it is often necessary to add the proper bacteria (rhizobia) to the seed or soil before planting, a process called "inoculation."

The Rhizobium: Legume Association

Early in the study of symbiotic nitrogen fixation, all nodule bacteria were considered one species capable of nodulating all leguminous plants. However, investigators soon learned that there were many kinds of rhizobia; those which nodulated certain species would not nodulate others. Furthermore, not all rhizobia capable of producing nodules on a particular host were beneficial to growth. Certain rhizobia produce nodules and live off their host without providing any nitrogen. Consequently, for maximum benefit to plant growth, rhizobia must be screened for their nitrogen-fixing capabilities in association with particular hosts. Effective symbiosis depends upon discreet matching of both symbionts.

The efficiency of a rhizobium:plant association can often be determined by examining nodulation of the root system. In contrast to effective nodules, which are generally large, few in number, pink to red inside, and located on the upper tap root, ineffective nodules are small, numerous, white in color, and scattered on the lateral roots.

Rhizobia and Inoculants

The rhizobia are microscopic, unicellular plants which multiply by binary fission. They exist only in the vegetative state and are highly susceptible to drying and temperatures in excess of 40° C. While the soil is their natural habitat, rhizobia are easily cultured in the laboratory when supplied with an energy source such as mannitol or sucrose, certain growth factors contained in yeast or plant extracts, mineral salts, and a minimal supply of oxygen.

In preparing inoculants, strains of rhizobia selected for their effectiveness on particular host plants are cultured to high populations in a liquid medium before being mixed with a heat-treated, finely-pulverized sedge peat which serves as a protective home or carrier for the bacteria until they are applied to seeds or soil. The inoculant--a moist, brownish-black powder teeming with millions of live rhizobia--is usually applied to leguminous seeds immediately before planting.

Effective inoculants for agriculturally important leguminous crops are available at most local seed stores but appropriate inoculants for most of the wild indigenous prairie legumes are more difficult to obtain. Nodulation data and inoculants required for most legumes of the prairie region are listed in Table 1.

The leguminous species listed are known to form nodules and work symbiotically in fixing atmospheric nitrogen. Practically all species have been grown in Nitragin greenhouses or growth chambers and tested for their abilities to symbiose effectively with various strains of nodule bacteria. Effective cultures of the microsymbiont are maintained in the Nitragin stock collection for preparation of the various special inoculants listed.

Inocula designated by letters are wide-spectrum inocula effective on agriculturally important crops and are available at most seed stores. The special inocula for individual legumes,designated by "Sp.",are prepared on request and available only from our Milwaukee laboratory.

Methods of Inoculating Seeds

Leguminous seeds do not generally provide a good habitat for rhizobia; they are applied to the seed simply because this is an easy, convenient way to implant the nodule bacteria into the soil or rhizosphere where the young seedling will develop. It is best to inoculate as close to planting time as is practical and to protect inoculated seed from hot, drying winds and direct sunshine until they are planted. When planted, inoculated seed should always be covered with soil or some type of mulch. Large numbers of live rhizobia on seeds favors early nodulation and stronger, more vigorous seedlings.

Leguminous seeds vary greatly in size, shape and physical characteristics. Inoculation methods must be adjusted to suit the seed. Normally, the seed is moistened with a small amount of water, skim milk, or sugar solution (6 to 8 ml. of liquid per kilogram of seed). The powdered inoculant, 7 or 8 g. per kilogram of seed, is then added and mixed thoroughly with the moistened seed. If the seeds are too wet, addition of more inoculant or a little dry soil is recommended. Unhulled seeds require quite

a bit more liquid than hulled seed. A wide-mouth glass fruit jar with lid makes a good container for inoculating small lots of seed.

With low quality seeds, chemical seed treatment is sometimes necessary to obtain acceptable stands. This presents another problem. Most chemical seed protectants will kill nodule bacteria applied to seed but will not harm rhizobia in the soil. The inoculum can be diluted with any inert organic material or screened soil and applied directly to the soil rather than to the seed. Another alternative is to inoculate a companion seed not treated with a fungicide and which is included in the seed mixture.

In many instances leguminous seeds are planted in seed flats or jiffy pots before transplanting to the field. The inoculum can easily be added directly in the seed furrows along with the seed. No further inoculation is necessary when the seedlings are transplanted to the field.

Special Methods of Inoculating Under Adverse Conditions

Busy schedules and labor shortages sometimes make it necessary to plant leguminous seed in dry, hot soils in anticipation of an early rain. While seeds can maintain vitality during sustained drought periods, the nodule bacteria are less fortunate. A pelleting technique of inoculation has proven quite effective under such conditions. Larger inocula are used and made into a slurry. Four or five times the usual amount of inoculum (18 grams per kilogram of seed) is mixed with a gum arabic solution (43% gum arabic) and applied to the seed in a fruit or peanut butter jar. The wet seeds are then mixed quickly with a very fine calcium carbonate powder (0.5 kg. $CaCO_3$ to 1.0 kg. seed) which coats and enables separation of the seeds for easy planting. Rhizobia encased in the pellet can usually withstand the hazards of hot, dry soils for 2 to 3 weeks in sufficient numbers to bring about effective nodulation when rain comes. When soils are not highly acid, the seeds can be coated with alfalfa meal, pulverized wheat straw, additional powdered inoculant, or even dry screened soils. Excellent results are usually obtained.

Development of New Inoculants

The Nitragin collection of rhizobia comprises around 1,150 strains of rhizobia obtained from 171 species in 61 genera of the family Leguminosae. While this collection is probably one of the largest, it represents only a small percentage of the 12,000 species of leguminous plants. Undoubtedly there are species of legumes indigenous to the Midwest Prairie for which there is currently no effective inoculum or strains of rhizobia for preparing one. This problem can be solved by a cooperative effort.

When new species of legumes are discovered and they are effectively nodulated, we would greatly appreciate receiving nodules so that new strains of effective rhizobia can be isolated and supplied to others who may be interested in growing these particular leguminous species. The roots should be washed quickly and segments of roots with large, healthy nodules on them should be cut, wrapped in moistened paper, put into a plastic bag, and mailed immediately to our laboratory. The rhizobia in these nodules will be isolated, cultured, tested for nitrogen-fixing ability, and used in preparation of inocula for you and your colleagues. Many of the inocula listed in Table 1 were made possible by this cooperative approach. Provision of effective rhizobia for the wild leguminous species is not done for profit but as a service to all who are working with this wonderful family of plants which are important in so many ways. They not only provide abundant supplies of protein food for man but they feed the birds and they enhance the beauty of the countryside.

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TABLE I. Symbiotic properties and appropriate rhizobia inocula for leguminous species found in the tall-grass region of North America.

LEGUMINOUS SPECIES	NODULATES	EFFECTIVE SYMBIOSIS	INOCULUM
*Alysicarpus vaginalis DC (alyceclover)	Yes	Yes	EL
Amorpha L. (amorpha)			
canescens Pursh (leadplant)	Yes	Yes	Sp.
fruticosa L. (indigobush a.)	Yes	Yes	Sp.
*Anthyllis vulneraria L. (kidneyvetch)	Yes	Yes	K
Astragalus L. (milkvetch; poisonvetch)			
canadensis L. (Canada m.)	Yes	Yes	Sp.
*cicer L. (cicer m.)	Yes	Yes	Sp.
*pectinatus (Hook.) Dougl. (narrowleafsp.	Yes	Yes	Sp.
Baptista Vent. (wild indigo)			
australis L. (blue w.)	Yes	Yes	EL
leucantha T. & G. (Atlantic w.)	Yes	Yes	EL
leucophaea Nutt. (plains w.)	Yes	Yes	EL
tinctoria L. (yellow w.)	Yes	Yes	EL
*Cajanus cajan Millsp. (pigeonpea)	Yes	Yes	EL
*Caragana arborescens Lam. (Siberian pea-shrub)	Yes	Yes	Sp.
Cassia L. (senna; partridgepea)			
fasciculata Michx. (showy p.)	Yes	Yes	Sp.
marilandica L. (wild s.)	Yes	Yes	Sp.
*Coronilla varia L. (crownvetch)	Yes	Yes	M
Crotalaria L. (crotalaria; rattlebox)			
sagittalis L. (arrow c.)	Yes	Yes	EL
Dalea alopecuroides Willd. (foxtail dalea)	Yes	Yes	Sp.
Desmanthus Willd. (bundleflower)			
illinoensis (Michx.) MacM. (Illinois b.)	Yes	Yes	EL
Desmodium Desv. (tickclover)			
canadense (L.) DC. (Canada t.)	Yes	Yes	EL
canescens (L.) DC. (hoary t.)	Yes	Yes	EL
*Dolichos lablab L. (hyacinthbean)	Yes	Yes	EL
*Hedysarum coronarium L. (sulla; sweetvetch)	Yes	Yes	Sp.
Hosackia americana (Nutt.) Piper (prairie trefoil; deervetch)	Yes	Yes	Sp.
Lathyrus L. (peavine)			
*hirsutus L. (rough p.)	Yes	Yes	C
japonicus L. (maritime p.)	Yes	Yes	C
*latifolius L. (perennial p.)	Yes	Yes	C
ochroleucus Hook. (cream p.)	Yes	Yes	C
*odoratus L. (sweetpea)	Yes	Yes	C
*sylvestris L. (flat p.)	Yes	Yes	C
*tingitanus L. (tangierpea)	Yes	Yes	C
venosus Muhl. (veiny p.)	Yes	Yes	C
*Lens culinaris Medic. (lentil)	Yes	Yes	C
Lespedeza Michx. (lespedeza; bushclover)			
bicolor Turcz. (shrub l.)	Yes	Yes	Sp.
capitata Michx. (roundhead l.)	Yes	Yes	EL
*cuneata (Dumont) G. Don (sericea l.)	Yes	Yes	Sp.
*daurica (Laxm.) Schindl. var. (rush l.) schimadae (Masam.) M. & Hosok.	Yes	Yes	Sp.
*hedysaroides (Pall.) Kitagawa (bush l.)	Yes	Yes	Sp.
hirta (L.) Hornem. (hairy l.)	Yes	Yes	EL
leptostachya (L.) Engelm (slender-spiked l.)	Yes	Yes	EL
procumbens Michx. (trailing l.)	Yes	Yes	Sp.
repens (L.) Bart. (creeping l.)	Yes	Yes	Sp.
Lotus L. (trefoil; deervetch)			
*corniculatus L. (birdsfoot t.)	Yes	Yes	K
pedunculatus L. (wetland d.)	Yes	Yes	Sp.
*tenuis Waldst. and Dit. ex. Willd. (narrow leaf b.t.)	Yes	Yes	K
americanus (Nutt.) Bisch. (See Hosackia)			

TABLE I. (Continued)

LEGUMINOUS SPECIES	NODULATES	EFFECTIVE SYMBIOSIS	INOCULUM
Lupinus L. (lupine)			
*albus L. (white l.)	Yes	Yes	H
*angustifolius L. (blue l.)	Yes	Yes	H
*luteus L. (yellow l.)	Yes	Yes	H
perennis L. (perennial l.)	Yes	Yes	H
piattensis S. Wats. (Nebraska l.)	Yes	Yes	H
Medicago L. (medic; burclover; alfalfa)			
*arabica (L.) Huds. (spotted b.)	Yes	Yes	Sp.
*falcata L. (yellow a.)	Yes	Yes	A
*lupulina L.(black m.)	Yes	Yes	Sp.
*sativa L. (alfalfa)	Yes	Yes	A
Melilotus Mill. (sweetclover)			
*alba Desr. (white s.)	Yes	Yes	A
*officinalis (L.) Lam. (yellow s.)	Yes	Yes	A
Oxytropis lambertii Pursh (lambert crazy-weed)	Yes	Yes	Sp.
Petalostemum Michx. (prairie clover)			
candidum (Willd.) Michx. (white p.)	Yes	Yes	Sp.
purpureum (Vent.) Rydb. (purple p.)	Yes	Yes	Sp.
Phaseolus L. (bean)			
*angularis Wight (adsuki b.)	Yes	Yes	EL
*aureus Roxb. (mung b.)	Yes	Yes	EL
*lunatus L. (lima b.)	Yes	Yes	Sp.
*vulgaris L. (common b.)	Yes	Yes	D
Pisum L. (pea)			
*arvense (L.) Poir. (field p.)	Yes	Yes	C
*sativum L. (garden p.)	Yes	Yes	C
Psoralea spp. L. (scurfpea)	Yes	Yes	Sp.
Robinia L. (locust)			
hispida (bristly l.)	Yes	Yes	Sp.
pseudo-scacia L. (black l.)	Yes	Yes	Sp.
Strophostyles Ell. (wildbean)			
helvola (L.) Ell. (trailing w.)	Yes	Yes	Sp.
pauciflora L. (leiosperma (T&G) Piper) (small w.)	Yes	Yes	Sp.
Tephrosia virginiana (L.) Pers. (goatstrue; Virginia tephrosia)	Yes	Yes	Sp.
Trifolium L. (clover)			
*hybridum L. (alsike c.)	Yes	Yes	B
*pratense L. (red c.)	Yes	Yes	B
*repens L. (white c., Dutch c.)	Yes	Yes	B
Vicia L. (vetch)			
americana Muhl. (American v.)	Yes	Yes	C
caroliniana Walt. (Carolina v.)	Yes	Yes	C
*cracca L. (bird v.)	Yes	Yes	Sp.
*dasycarpa Ten. (woollypod v.)	Yes	Yes	C
*faba L. (broadbean) var. equina Pers. (V. faba L. subsp. major Alef.) (horsebean)	Yes	Yes	C
*villosa Roth (hairy v.)	Yes	Yes	C
Gleditsia triacanthos L. (honeylocust)	No	No	--
Gymnocladus dioica (L.) K. Koch (Kentucky coffeetree)	No	No	--

*Species introduced from other continents.

U. W. ARBORETUM CURTIS PRAIRIE, MADISON

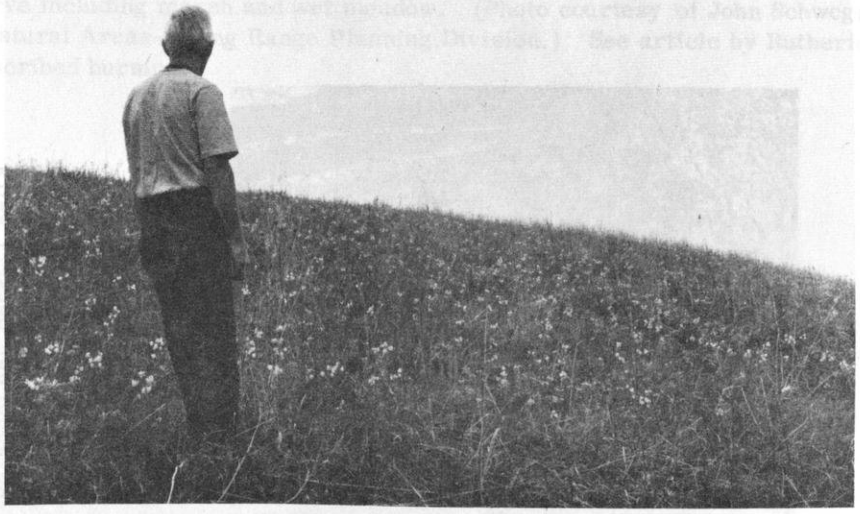
A study tour in progress near fencerow oaks opening. (Photo by Ron Austin.) Northeast of study sites of Riechert, Lussenhop, and Hole. Silt loam soil.

U. W. ARBORETUM GREENE PRAIRIE, MADISON

In lower background, as viewed southward from dry black oak-prairie savanna on west knoll. (Photo by Jim Cartter) Sandy loam soil. The narrow foot trail leads into the wider fire lane here.

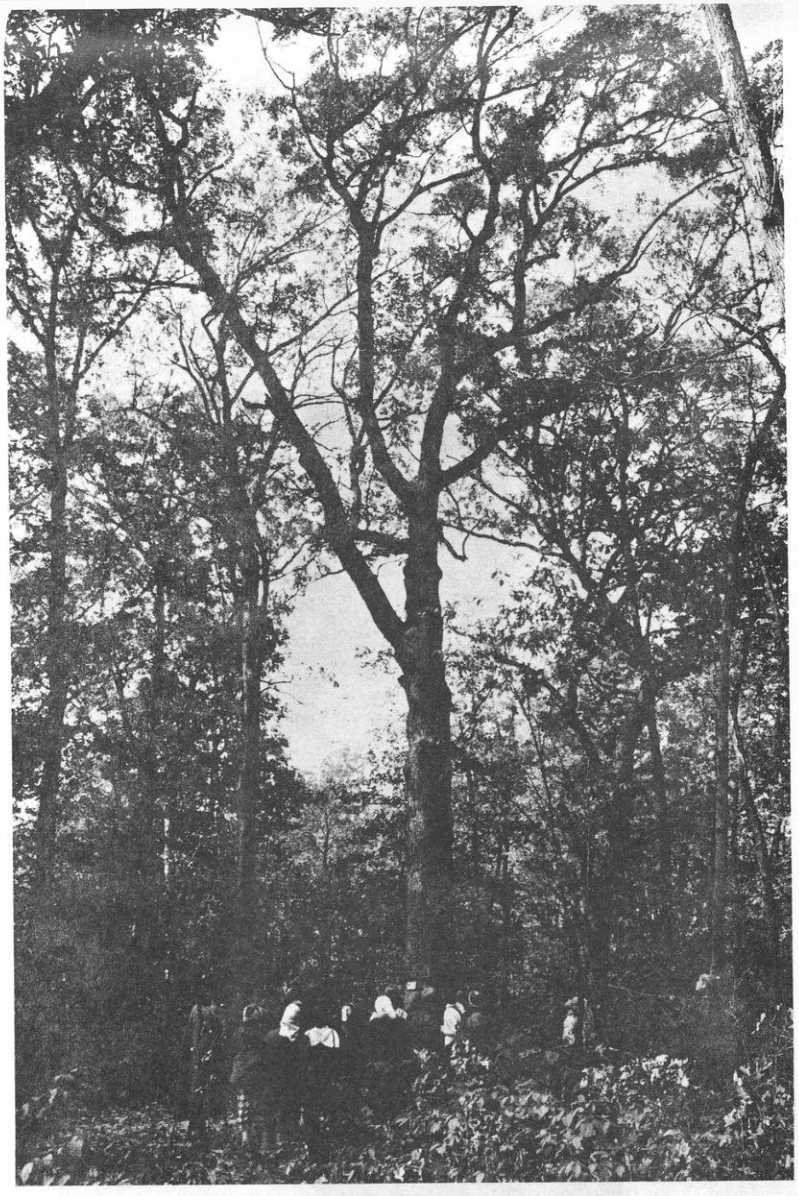
CHIWAUKEE PRAIRIE, KENOSHA COUNTY, WIS.

Summer aspect, looking southwest. (Photos by F. G. Schmidt.) See articles by Krampert and Sander
Wet to dry sandy old beach ridges.



OLIVER PRAIRIE, GREEN COUNTY, WIS.

Looking west in late May. (Photos by Virginia Kline.) Site of Riechert study. Thin soil over dry limestone outcrop. Dodecatheon meadia plants in flower among unburned stalks of grasses and forbs of the previous summer.



MADISON SCHOOL FOREST, VERONA, WIS.

130-year-old oak forest resulting from fire stoppage in oak-prairie savanna; birthplace of Madison Public Schools' Outdoor Education Program (see article by Kline.) Sand and loess over dissected unglaciated St. Peter Sandstone.

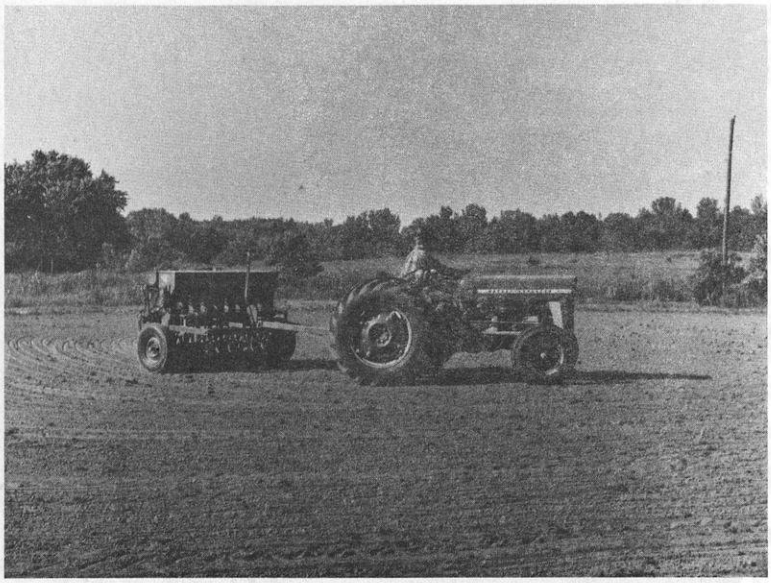
GOOSE LAKE PRAIRIE, GRUNDY COUNTY, ILL.

An Illinois Nature Preserve including marsh and wet meadow. (Photo courtesy of John Schwegman, Ill. Dept. of Conservation, Natural Areas--Long Range Planning Division.) See article by Rutherford. Note shrubs controlled by prescribed burning.

GRETHER - FIGURE II

White pine habitat at top of cliff above abandoned glacial drainage channel at Rocky Arbor Park near Wisconsin Dells.

G

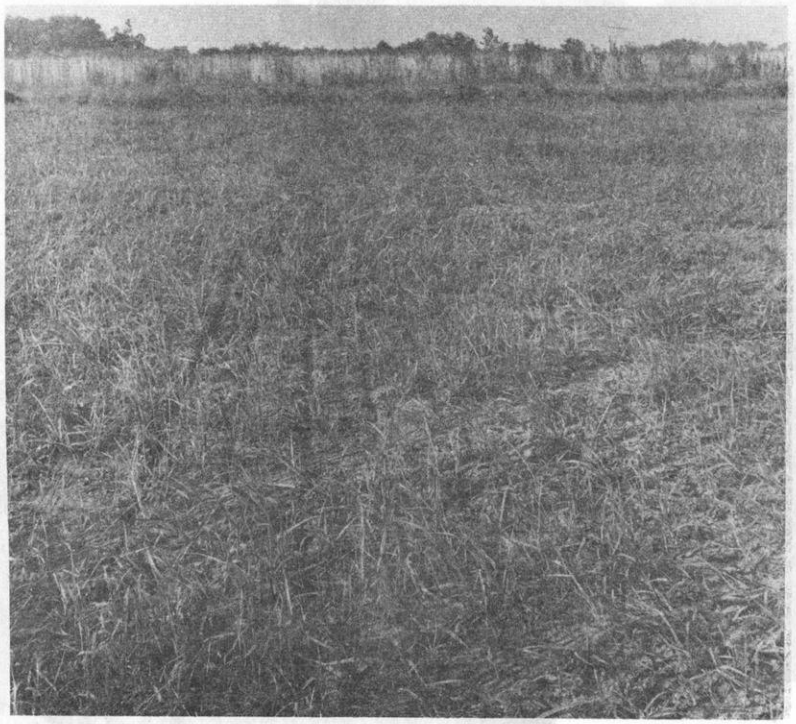


SCHRAMM FIGURE I

Planting With The Nisbet Seed Drill

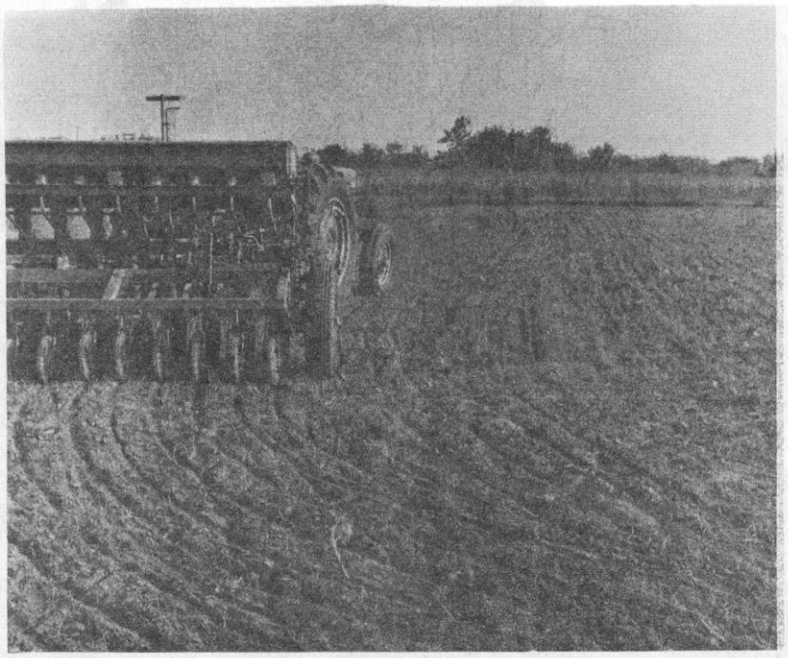
SCHRAMM FIGURE II

Corner of a Small One Acre Planting After it was Gone Over Three Times by The Drill



SCHRAMM FIGURE III

The Earlier Grass Planting (Planted June 30) as it Appeared After the Forb Drilling on August 10



SCHRAMM FIGURE IV

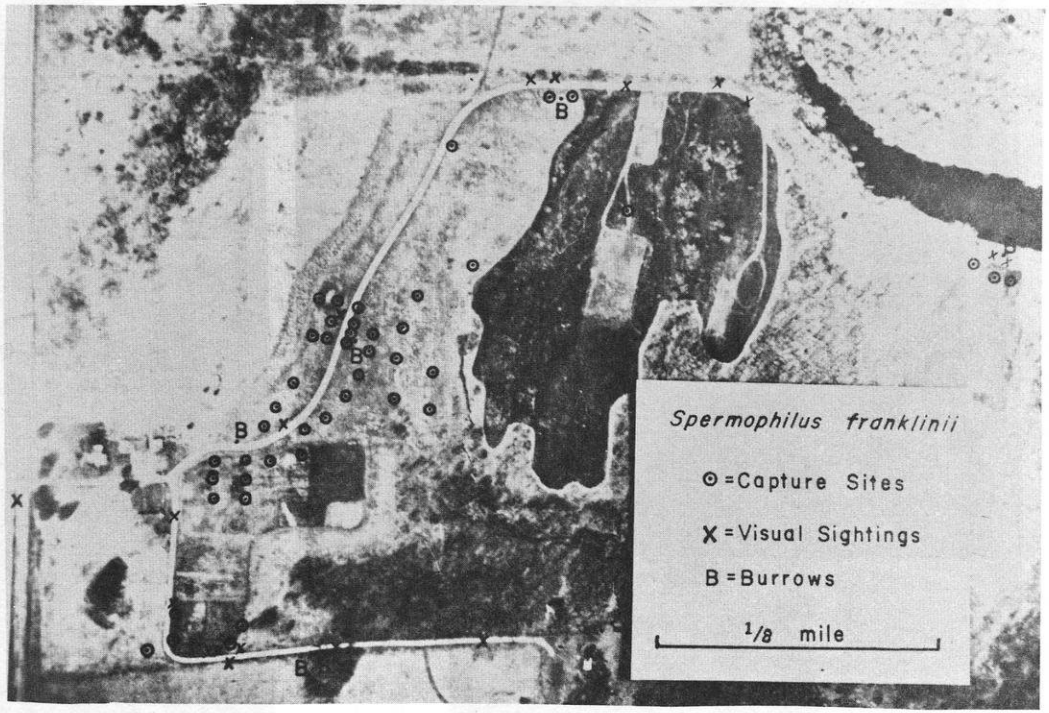
The Later Grass Planting (Planted July 15) as it Appeared During the Forb Planting on August 10

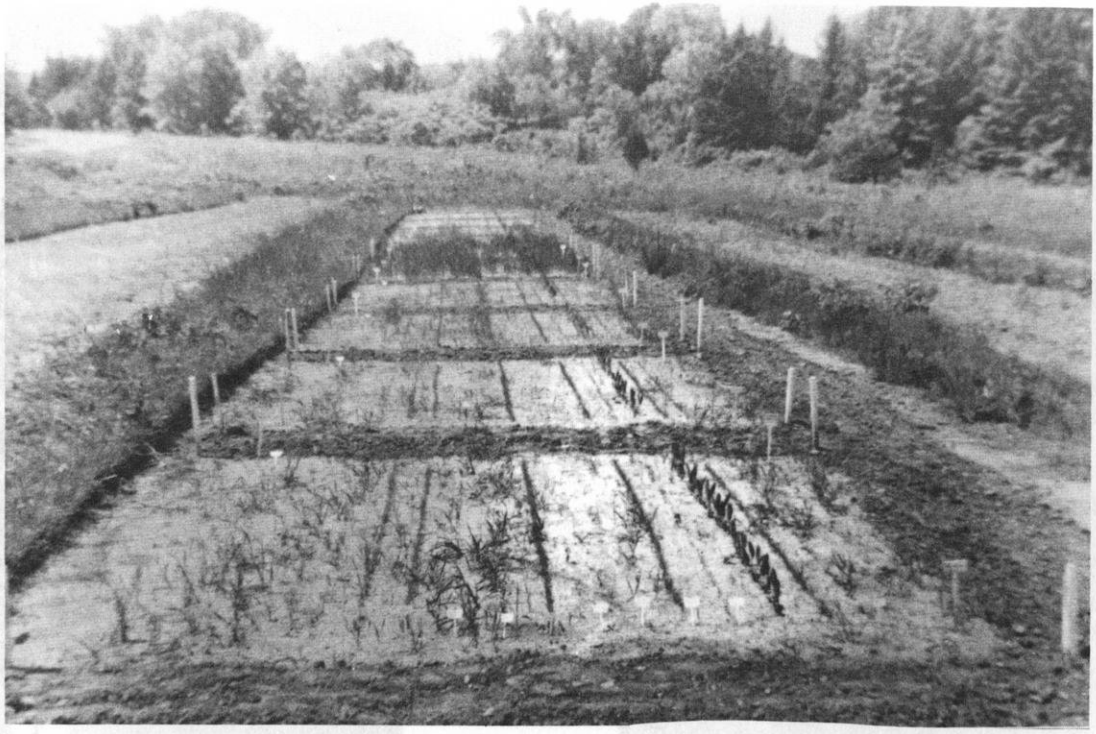
SCHRAMM FIGURE V

The Earlier Grass Planting as it Appeared The Following Spring (April, 1971). Even After Winter Snows This Mixed Stand of Grass Less Than One Year Old is Over One-half Meter High.

VAN PETTEN - FIGURE II

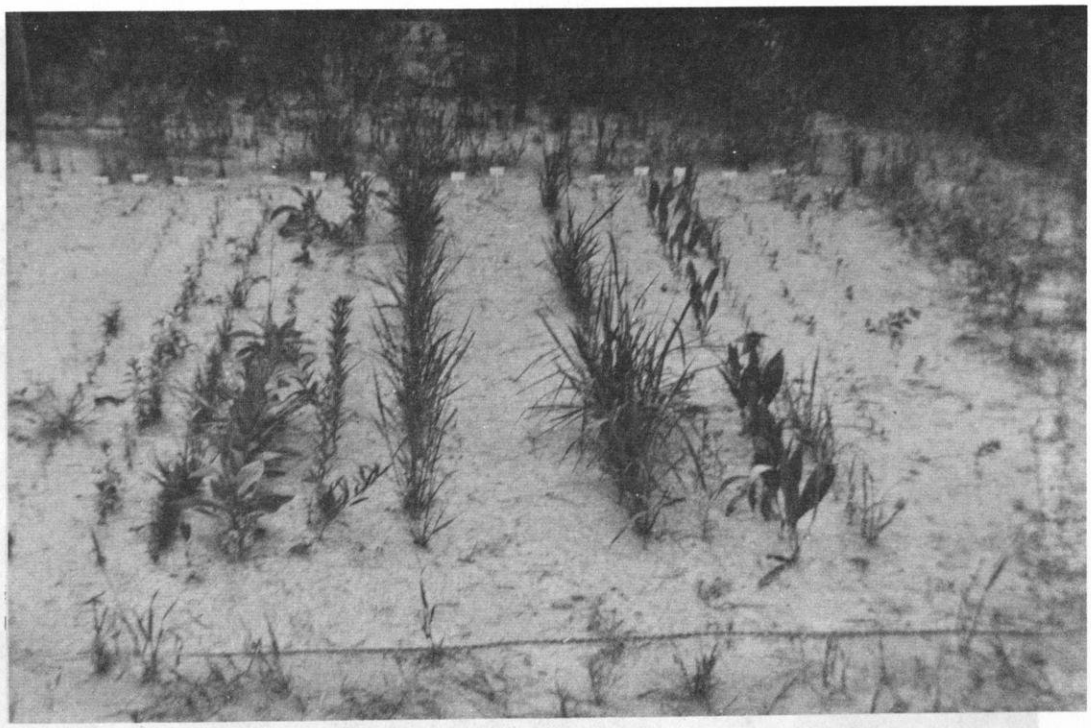
Aerial photo of study area showing capture sites, visual sightings and burrow locations for the 1970 summer period.





SCHWARZMEIER FIGURE IV

Seeded-rows experiment on 17 June, 1969, with plot 10 in the foreground. Note the rapid growth of oats midway in the strip.



SCHWARZMEIER FIGURE V

Seeded-rows experiment on 15 August, 1969, showing patches of retardation in plot 1.

SCHWARZMEIER FIGURE VI

Plug-rows experiment on 3 August, 1969, with plot 3 in foreground. Note the last two plots, 6 and 7, are still very open.

ZIMMERMAN FIG. 2A

A flat of seedlings of Dodecatheon meadia in their second May; the second wintering outdoors triggered additional germination. Note forefinger for scale.

ZIMMERMAN FIGS. IIB, III

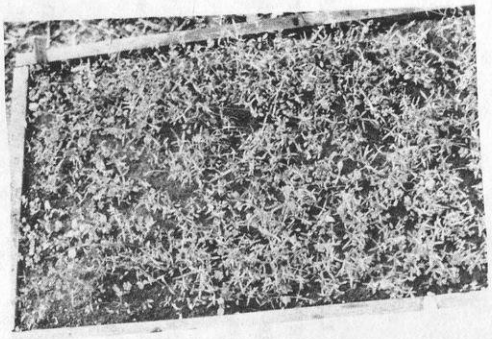
IIB (upper right) Geum triflorum transplants 5 cm apart in a greenhouse flat (note larger size than in IIIA). White "Pearlite" was being tried out to hinder surface drying of soil.

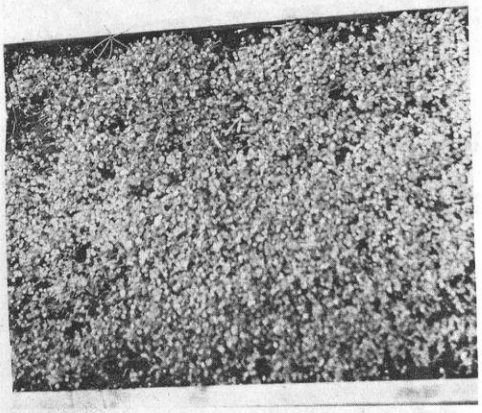
IIIA (upper left) Geum seedlings nearly ready to transplant for the first time to a greenhouse flat, at age of about three months.

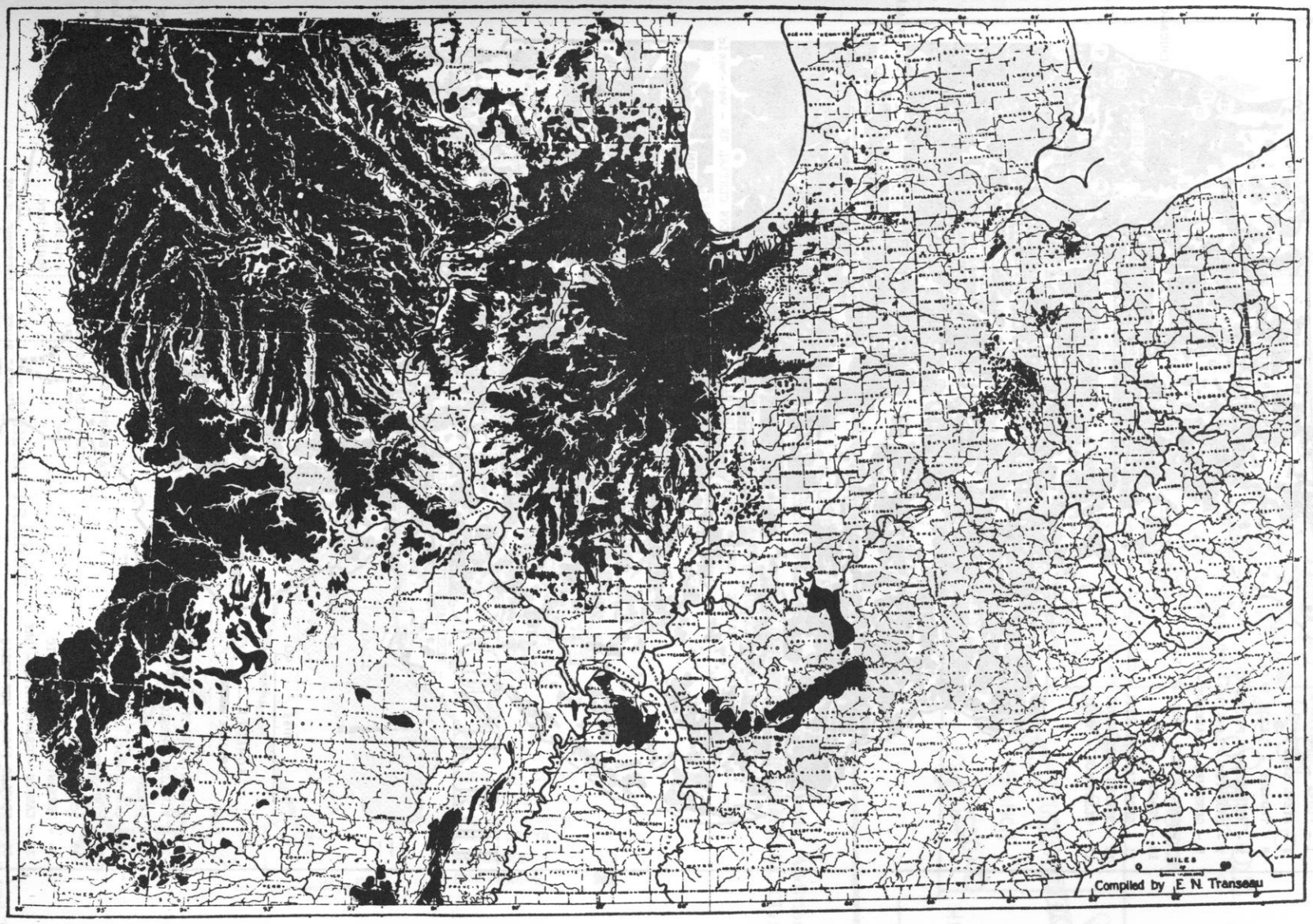
IIIB (lower right) Two-year-old Geums in August after second transplant to garden plot rows and watered throughout the summer. Some of these plants flowered in September.

ZIMMERMAN FIG. IV. A (top) Three-month-old Anemone patens seedlings in late August, not yet transplanted, when kept continually moist and partly shaded in greenhouse.

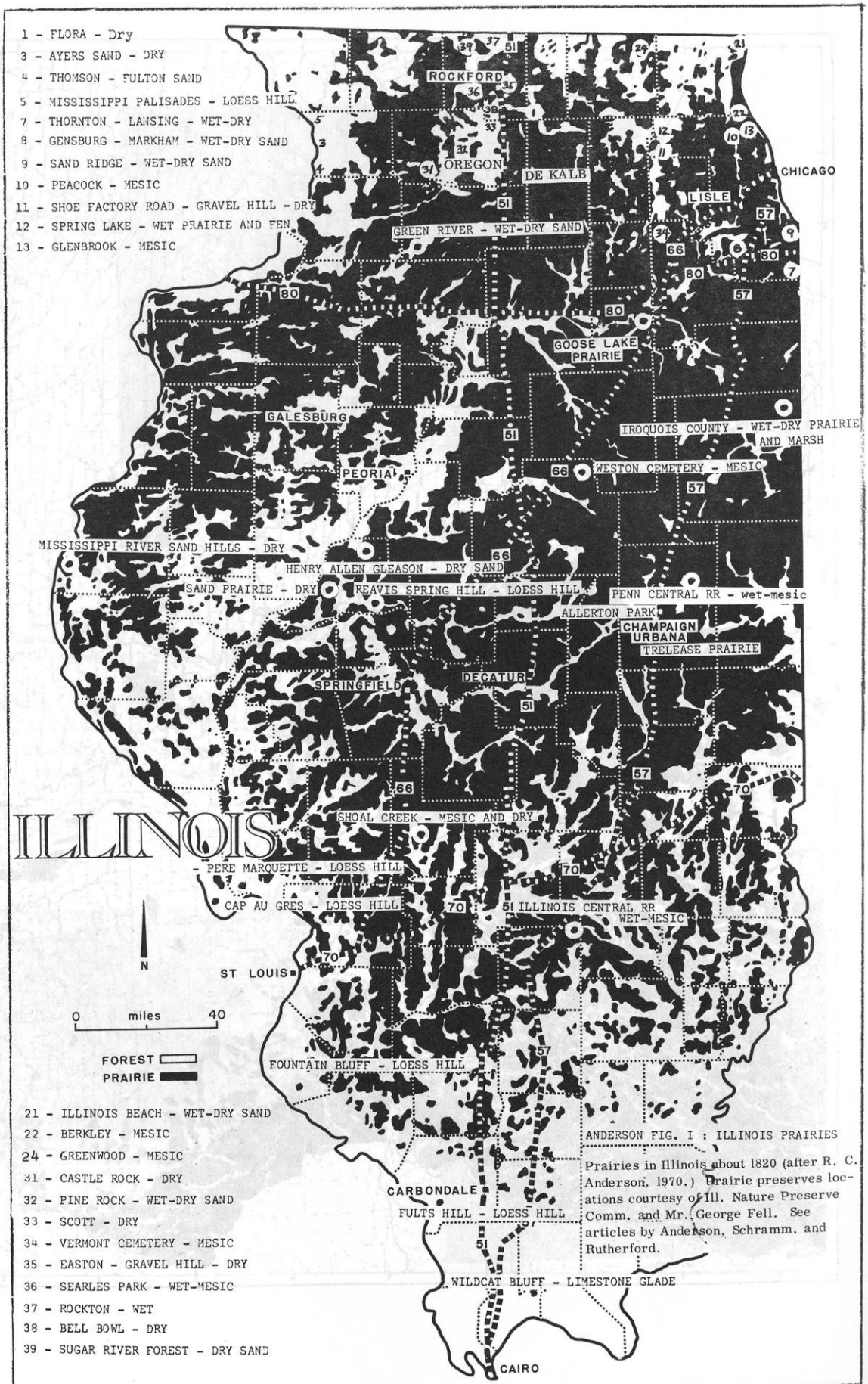
B. (bottom) Left, flat of Phlox pilosa seedlings in their first June in greenhouse, sowed thickly in March. Right, flat of Dodecatheon meadia seedlings in their first June in greenhouse, sowed thickly in March. The tiny dormant roots remained visible on soil surface through the summer and fall and were vulnerable to drying out.





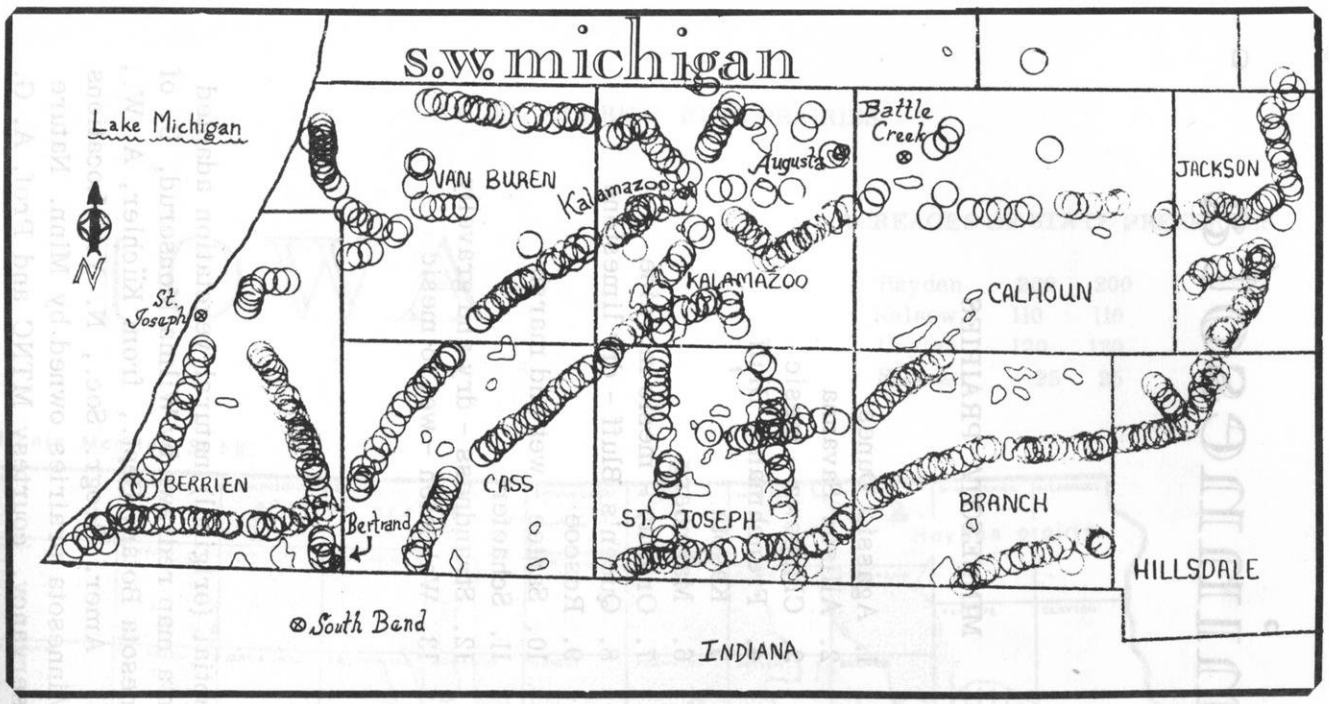


THE PRAIRIE PENINSULA WITH OUTLIERS. Reprinted with permission from Transeau, E. N., 1935, "The Prairie Peninsula." Ecology 16:423-437.



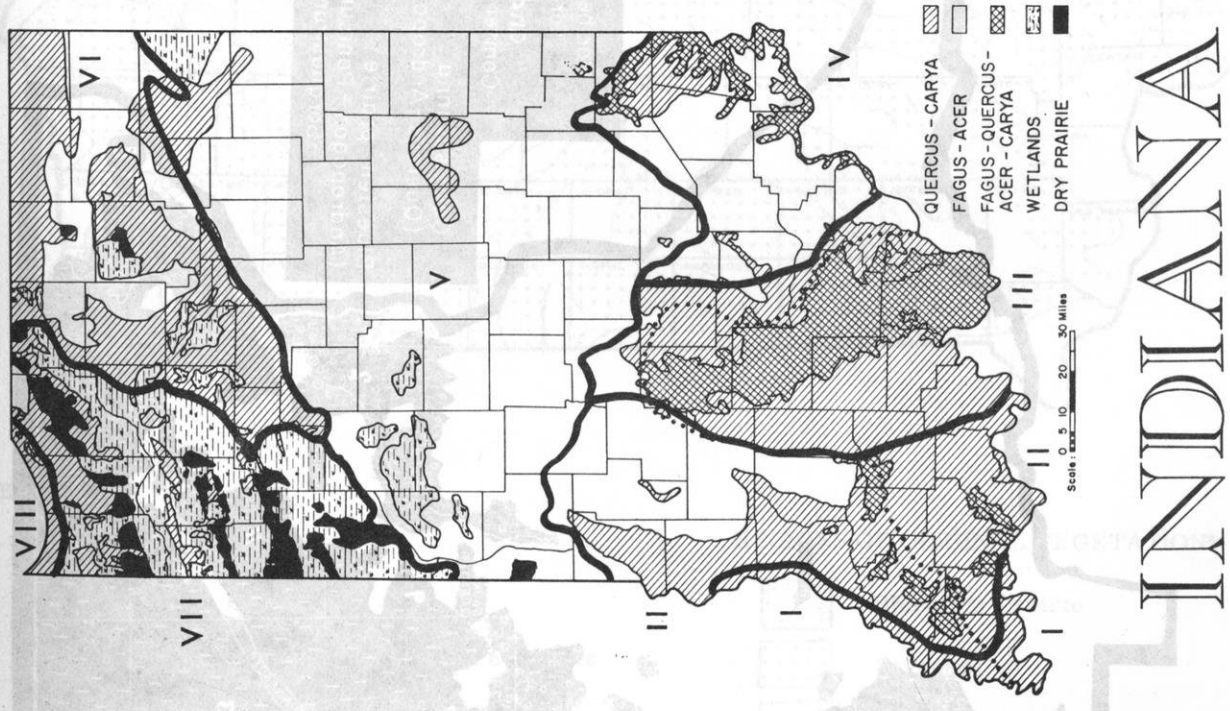
ANDERSON FIG. I : ILLINOIS PRAIRIES

Prairies in Illinois about 1820 (after R. C. Anderson, 1970.) Prairie preserves locations courtesy of Ill. Nature Preserve Comm. and Mr. George Fell. See articles by Anderson, Schramm, and Rutherford.



SCHARRER FIG. I. SOUTHWEST MICHIGAN PRAIRIES

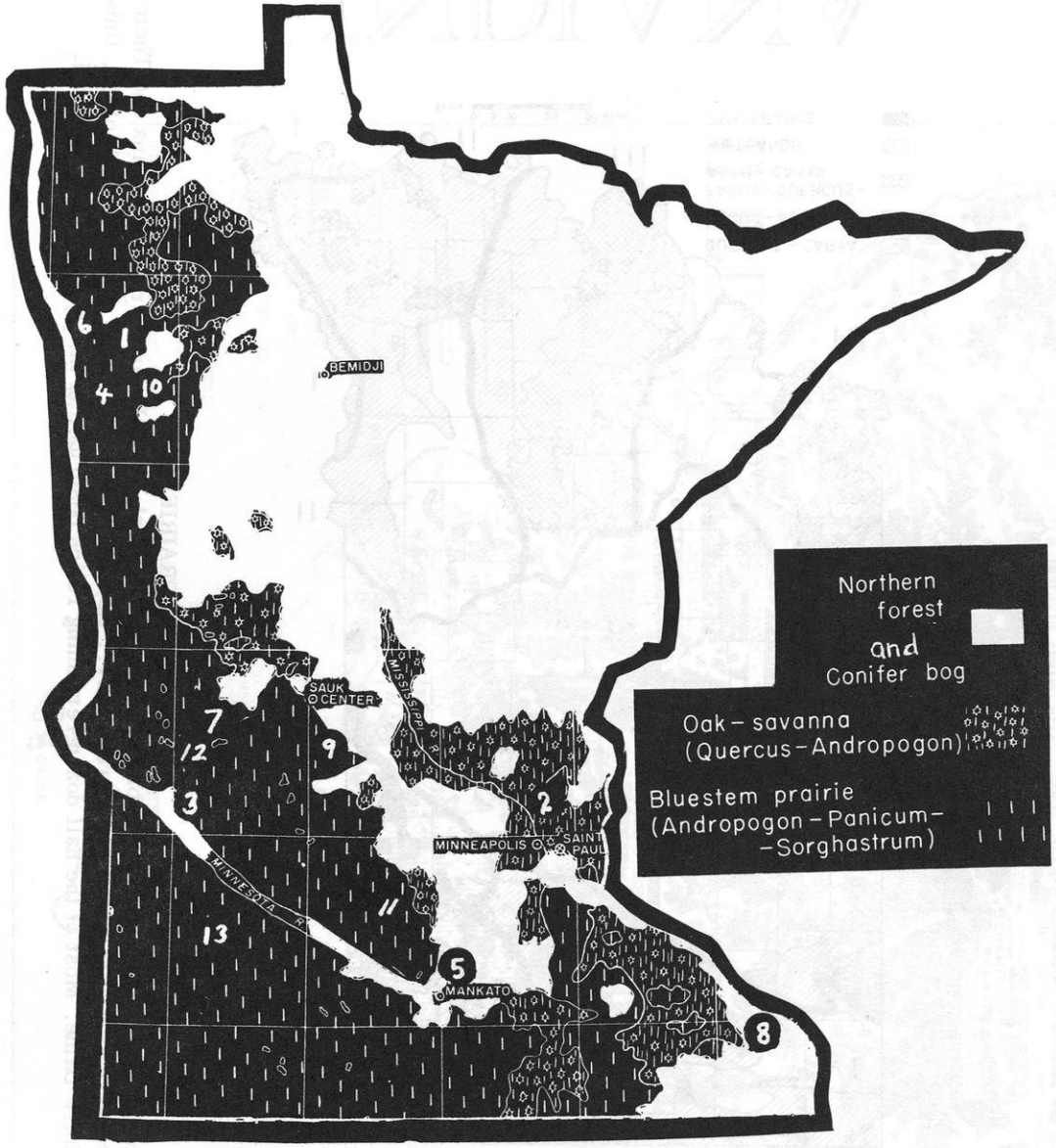
Prairies investigated are indicated by rows of circles - mostly following railroads. Additional sites mentioned by Thompson, but outside this area, include Huron River (Clinton), St. Clair River (Algonac), Alma College (Newaygo), Island Lake, Monroe County, Dayton.



INDIANA PRAIRIES

Map printed with permission from Lindsey, A.A., et al. 1970. Natural Areas in Indiana and Their Preservation. Rept. Ind. Nat. Areas Surv., Reprint ed., Amer. Midl. Nat., Dept. Biology, Univ. Notre Dame. Most of the half dozen remaining relics described in this book are in region VII.

minnesota



MINNESOTA PRAIRIES

1. Agassiz Dunes
2. Allison Savanna
3. Chippewa - mesic
4. Frenchman's Bluff
5. Kasota
6. Malmberg
7. Ordway - mesic moraine
8. Queen's Bluff - dry limestone
9. Roscoe
10. Santee - wet and marsh
11. Schaefer
12. Strandness - dry and gravelly
13. Wahpeton - wet to mesic

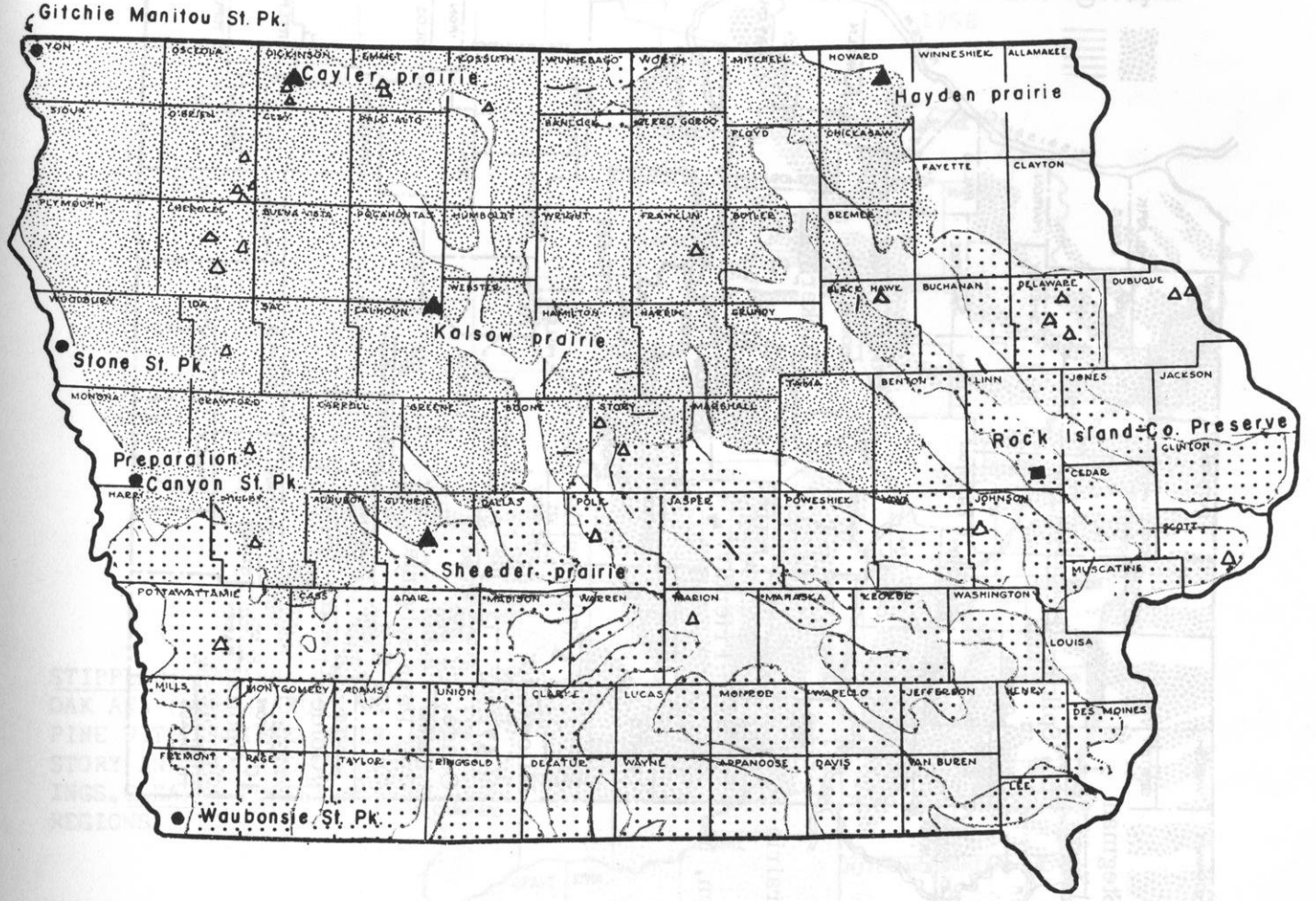
Potential (original) natural vegetation adapted from a map redrawn by Wilma Monserud, U. of Minnesota Botany Dept., from Küchler, A. W., 1964. Amer. Geogr. Soc., N. Y. Locations of Minnesota prairies owned by Minn. Nature Conservancy, courtesy MTNC and Prof. A. G. Johnson, U. of M. Dept. of Horticulture.

CAWLEY FIGURE I: IOWA PRAIRIES

IOWA

ACREAGES OF STATE PRESERVES

Hayden	200	200
Kalsow	110	110
Cayler	120	120
Sheeder	25	25



LEGEND

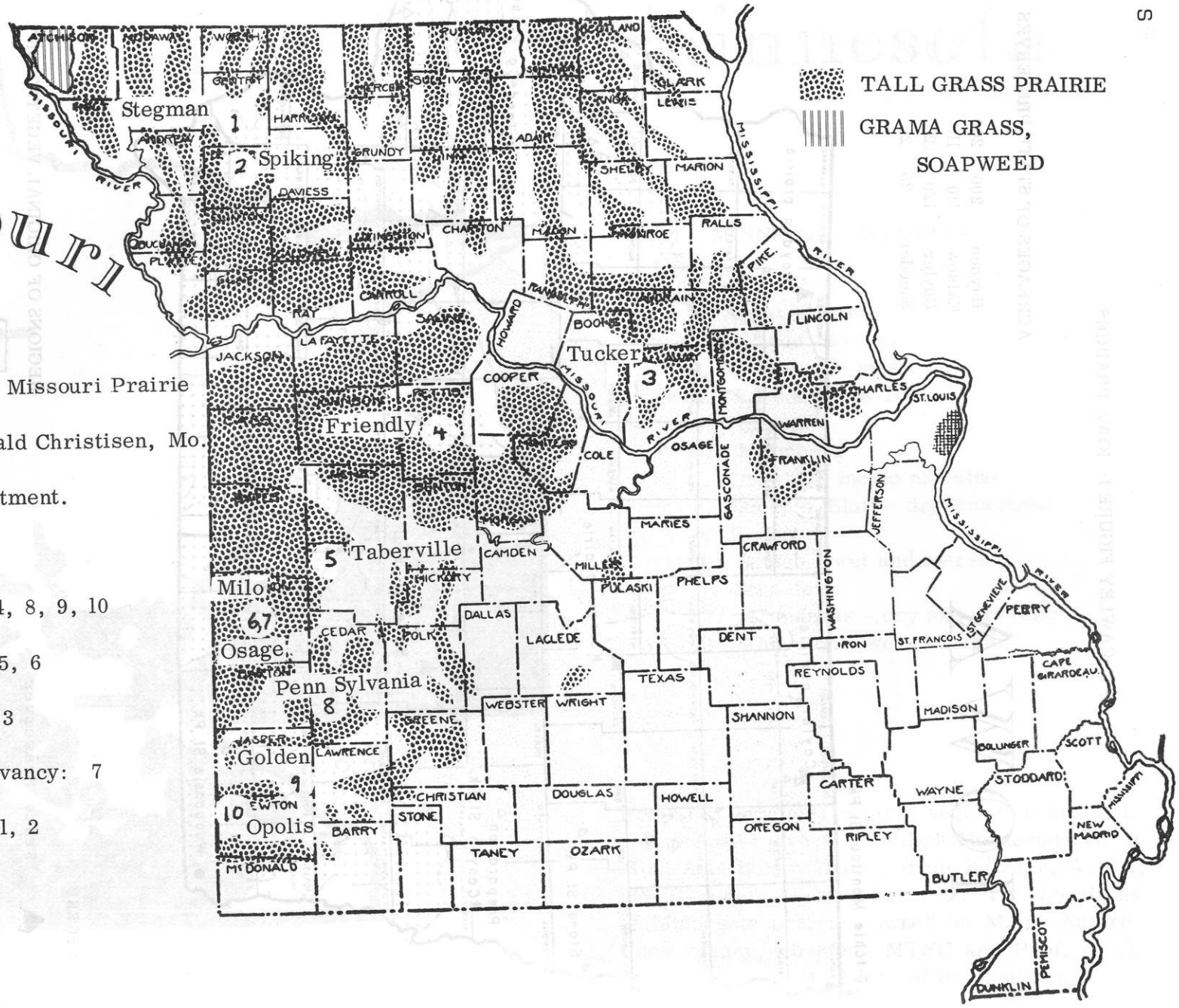
- ▲ State Preserves
- ■ County Preserves
- ● State Parks with Prairie Areas
- △ Prairie Area Not Protected
- — Railroad Prairies

REGIONS OF ORIGINAL VEGETATION*

- Bluestem Prairie
- Savanna
- Forest

*From Weller, M.W. 1969. Distribution of the Yellow-headed Blackbird in Iowa. Ia. Bird Life 39 (1): 3-5.

Missouri



Map courtesy of the Missouri Prairie Foundation and Donald Christisen, Mo. Conservation Department.

Ownership:

Mo. Prairie Fdn: 4, 8, 9, 10

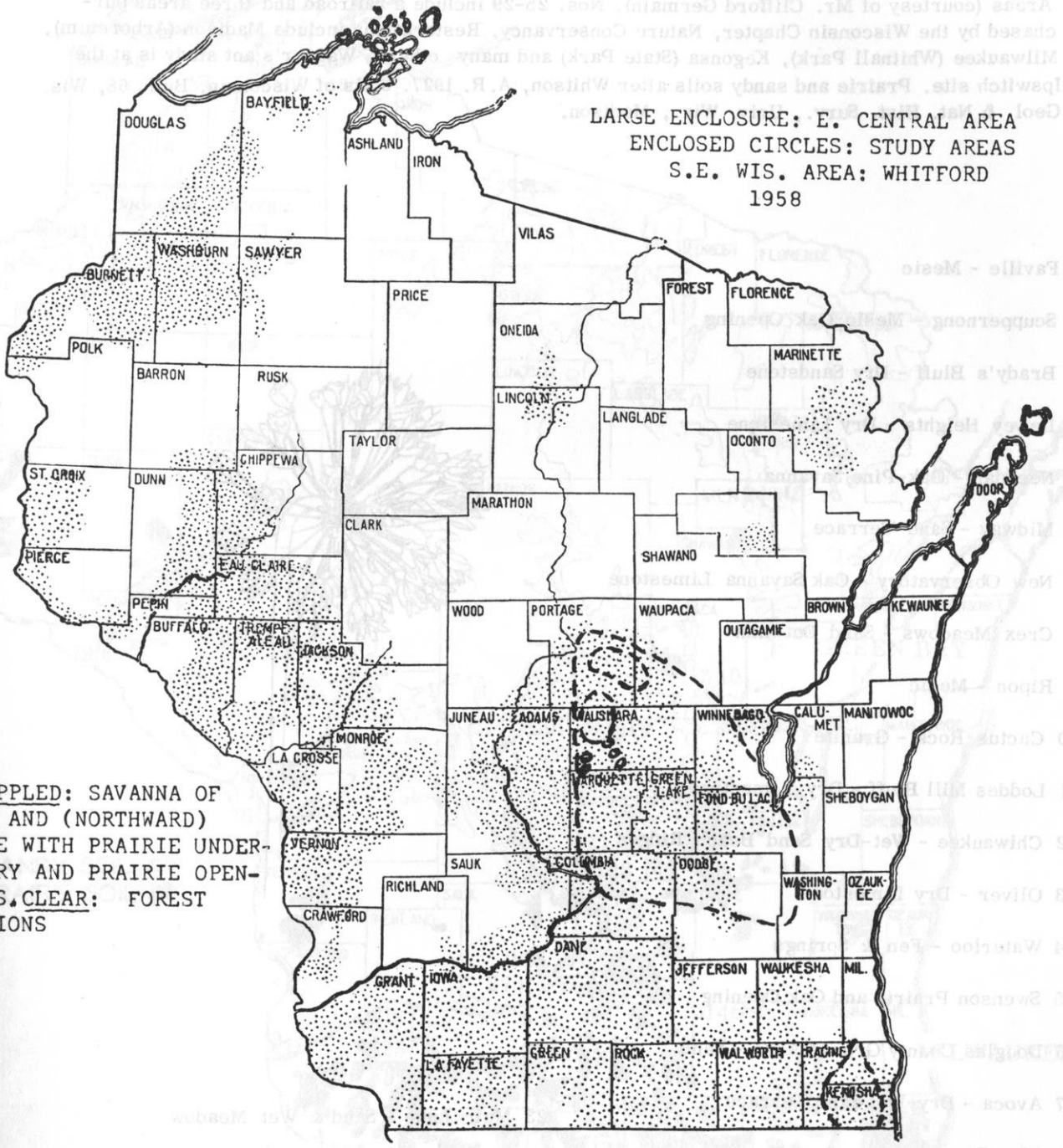
Mo. Cons. Dept.: 5, 6

Univ. of Mo.: 3

Mo. Nature Conservancy: 7

Private: 1, 2

Wisconsin



WHITFORD FIG. I - WISCONSIN: ORIGINAL PRAIRIE AND STUDY SITES

Pre-settlement vegetation adapted from map, "Early Vegetation of Wisconsin," Wis. Geol. & Nat. Hist. Surv. 1965.

U

WISCONSIN: PERTINENT SOILS AND PRAIRIE SITES

Prairie sites Nos. 1-24 are publicly-owned tracts designated by the State Board for Scientific Areas (courtesy of Mr. Clifford Germain). Nos. 25-29 include a railroad and three areas purchased by the Wisconsin Chapter, Nature Conservancy. Restorations include Madison (Arboretum), Milwaukee (Whitnall Park), Kegonsa (State Park) and many others. Wagner's ant study is at the Ipswitch site. Prairie and sandy soils after Whitson, A.R. 1927. Soils of Wisconsin. Bull. 68, Wis. Geol. & Nat. Hist. Surv., Univ. Wis., Madison.

1 Faville - Mesic

2 Scuppernong - Mesic; Oak Opening

3 Brady's Bluff - Dry Sandstone

4 Dewey Heights - Dry Limestone

5 Necedah - Oak-Pine Savanna

6 Midway - Sand Terrace

7 New Observatory - Oak Savanna Limestone

8 Crex Meadows - Sand Outwash

9 Ripon - Mesic

10 Cactus Rock - Granite

11 Loddes Mill Bluff - Dry Limestone

12 Chiwaukee - Wet-Dry Sand Beach Ridges

13 Oliver - Dry Limestone

14 Waterloo - Fen & Springs

15 Swenson Prairie and Oak Opening

16 Douglas County Grouse Area - Sand

17 Avoca - Dry-Wet Sand Terrace

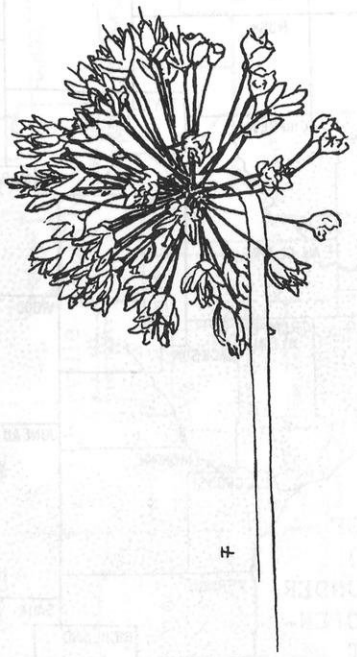
18 Blue River Dunes - Sand Terrace

19 Five Mile Bluff - Dry Limestone

20 Moquah Barrens - Sandy Pine

21 Buena Vista Prairie & Meadow - Sand

22 Kettle Moraine Fen & Low Prairie



23 Muir Lake - Sand & Wet Meadow

24 Fountain Creek - Sand

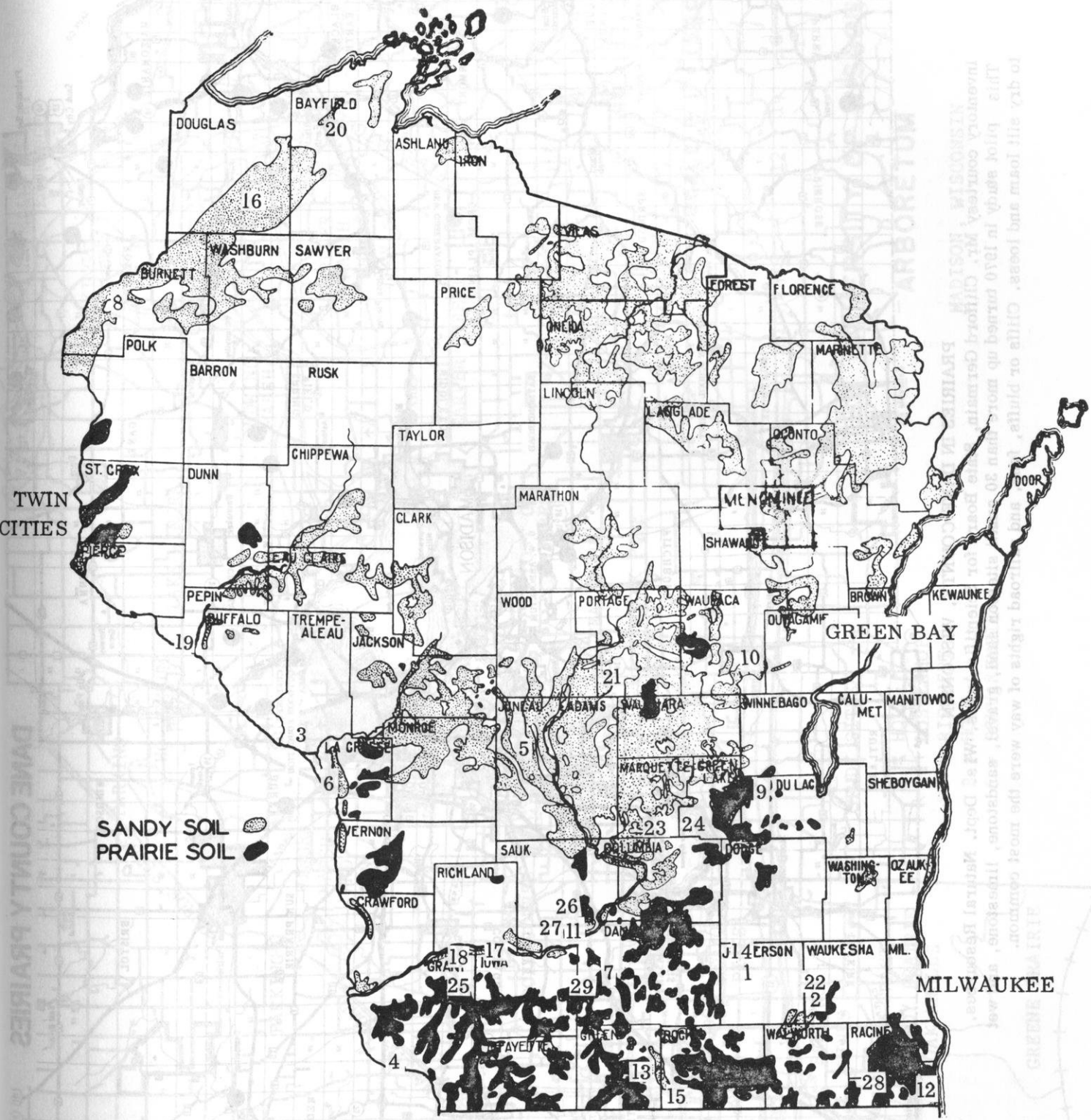
25 Ipswitch - (R.R.) Mesic

26 Devil's Lake - Quartzite Dry

27 Schluckebier - Sand Outwash (N.C.)

28 Benedict - Mesic (N.C.)

29 Thousands Rock Point - Dry Limestone (N.C.)



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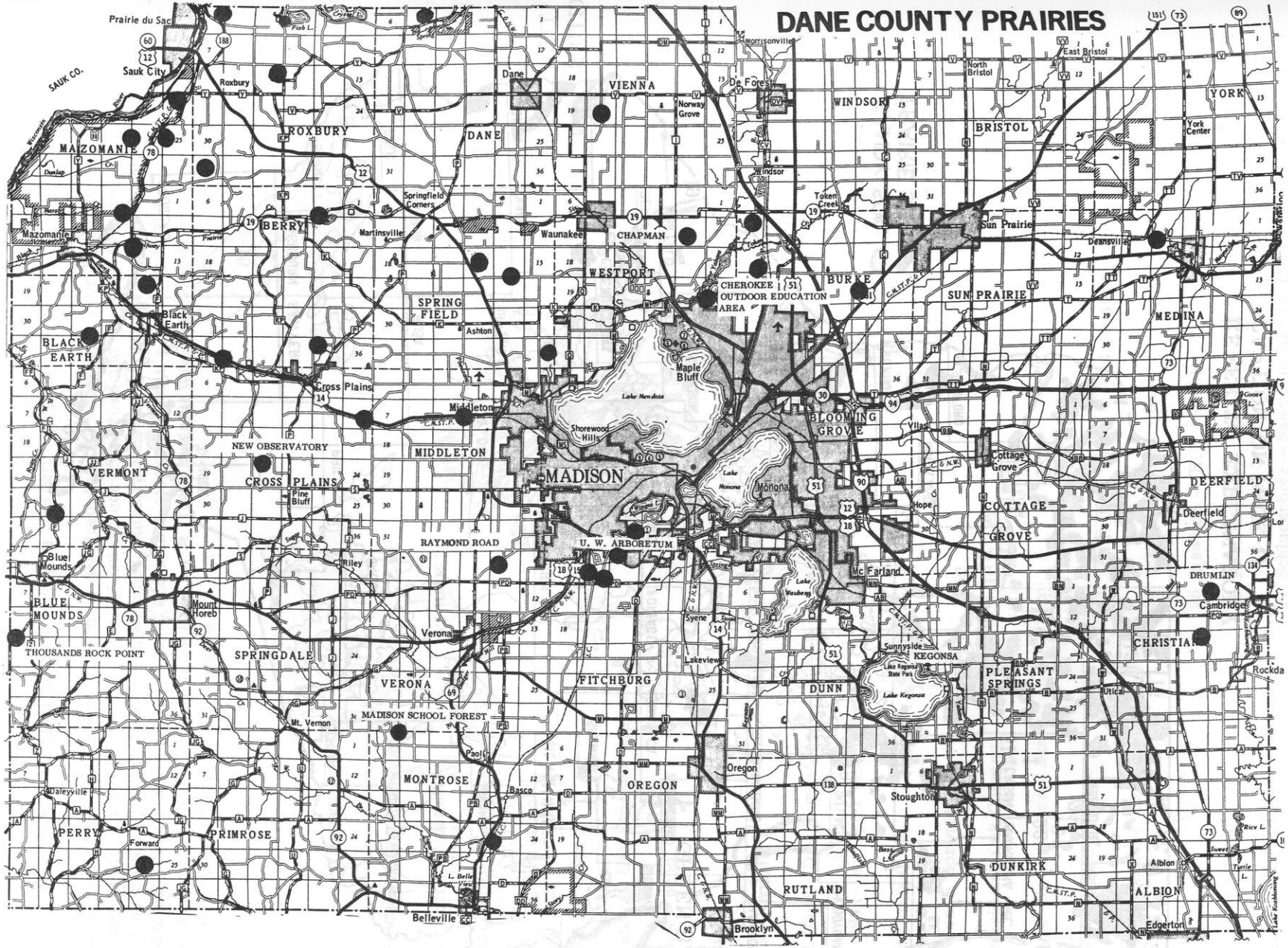
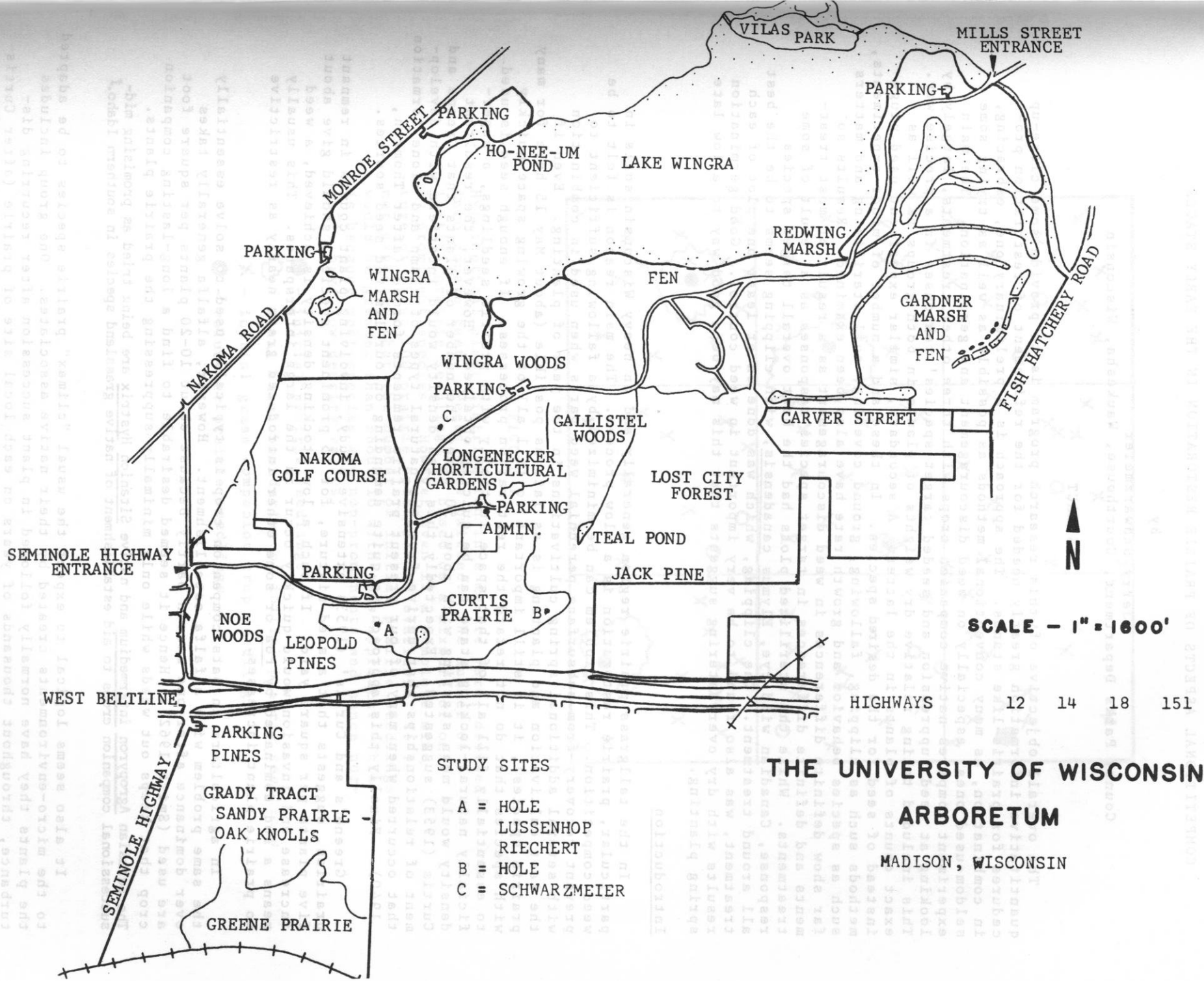


PRAIRIES IN DANE COUNTY, WISCONSIN

Inventory courtesy Mr. Clifford Germain, State Board for Scientific Areas, Wis. Dept. Natural Resources. This pilot study in 1970 turned up more than 30 small sites on sand, gravel, sandstone, limestone, and wet to dry silt loam and loess. Cliffs or bluffs, fens, and railroad rights of way were the most common.



THE UNIVERSITY OF WISCONSIN ARBORETUM

MADISON, WISCONSIN

COMPETITIONAL ASPECTS OF PRAIRIE RESTORATION IN THE EARLY STAGES

By

Jerry Schwarzmeier
County Parks Department, Courthouse, Waukesha, Wisconsin

ABSTRACT

The overall objective of this research program is to provide some close-up quantitative information greatly needed for the refinement of restoration procedures for prairie-like stands. The approach is a preliminary one, embracing, in combination, as many conventional methods as possible as well as trying some seldom-used ones, especially on weed discouragement and germination. The main experiment compares native companion crops with three other treatments, largely by looking at weed suppression and seeded target species' responses in a precise way. This included taking relative dry weights of plants in both groups as well as exact counts of plants in the latter. A secondary, similar experiment used plugs instead of seed for the desired species. In these and a number of minor experiments, methods such as clipping, fallowing, ground covering, soil sterilizing and matters such as species behavior and growth rate have also been examined. Results so far show definite differences in weed discouragement as a result of most treatments and definite differences in target species responses as a result of some treatments. While the sterilized plots had the best overall target species response, Canadian wild rye, Elymus canadensis, with clipping seems to be the best all around treatment. The clipping, which was done on at least one plot of each treatment, was also found to be very important in weed control. Good germination results with dry overwintering suggests that this may be a good way to allow late spring planting.

Introduction

In the tallgrass prairie region generally and on heavy Wisconsin soils in particular, prairie restoration is a slow process. The main reason is felt to be weed competition. This problem can be minimized by a fallowing sufficient to prevent recovery from subsurface perennial weed parts when used in combination with several additional spring cultivations in the year of planting. Even if the last cultivation and planting is as late as possible (about May 15 here for many prairie species), it is still important to fill all of the growing space quickly with species that do not retard the restoration processes. If enough seed is used to essentially fill all of that space initially with prairie seedlings, a superficially natural-looking stand can be quickly obtained. However, the resultant density would mean starting with about 50 times the number of plants that Greene and Curtis (1953) suggested. Expectedly this high density would interfere with development of relationships that derive from the natural types of clump and clone formation that occurred when many of our present prairie remnants formed (after Thomson, 1940). Finally this approach is quite demanding on our limited seed sources.

Greene's and Curtis' (1953) extensive study, involving plant counts in remnant prairies, suggests that a seed mixture, for 15 prominent species, should give about five plants per square yard. If such a low stocking density is achieved, a weed increase and invasion would quickly occur in the large interspaces. This usually means a sod dominated by Poa or some other introduced grass nearly as restrictive to prairie plant increases.

In agriculture an oats companion crop is typically used to solve essentially the same problem with alfalfa establishment. However, alfalfa generally takes over dominance after one season partly because about 10-20 plants per square foot are used (Smith 1962). Hence it seemed desirable to find a long-lasting companion crop that keeps out weeds while only minimally suppressing the prairie plants. The Eurasian Agropyron intermedium and native Sitanion Hystrix are being tried as promising mid-successional companion crops to aid establishment of native grassland species in southern Idaho.[1]

It also seems logical to expect the usual "climax" prairie species to be adapted to the micro-environments created by their native associates. One group includes the plants they have normally followed in plant succession after recurring disturbance, throughout thousands of years on each local site of prairie (after Curtis 1959). Such micro-environmental differences can be quite decisive (Risser 1969).

[1] Dr. Min Hironaka, Moscow, Idaho, pers. comm.

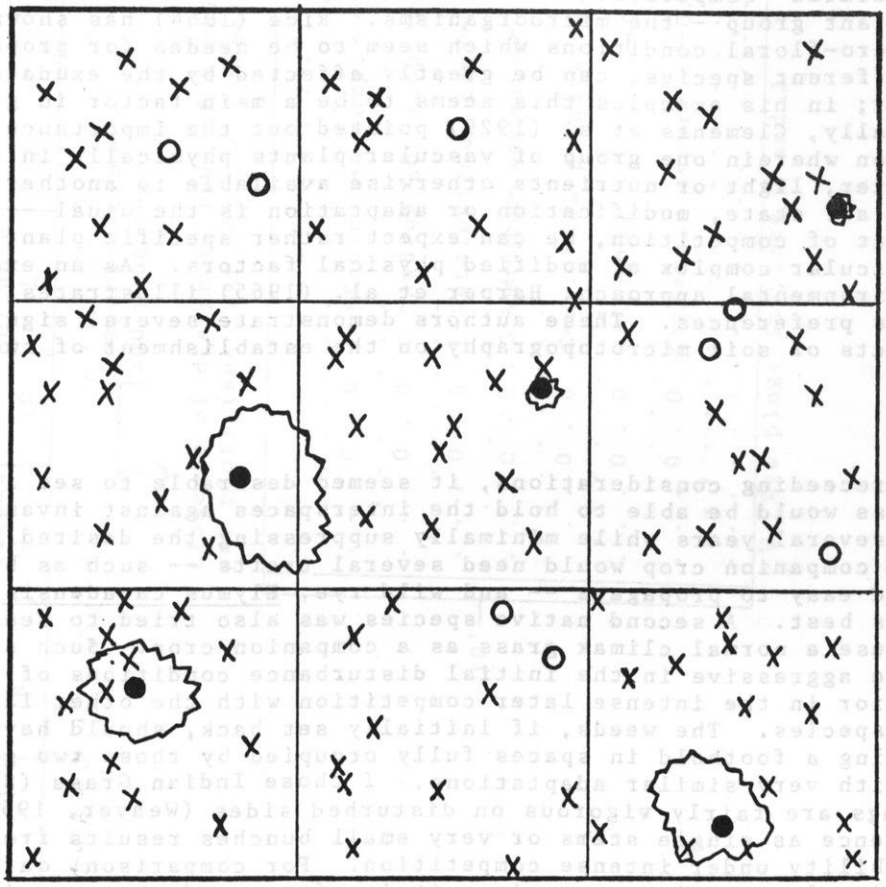


FIGURE I

Hypothetical plant distribution in a square yard, divided into square feet. Weeds were omitted. The number of initial prairie seedlings is based on a mixture of only 15 prominent species. However even if a complete mixture of about 100 prairie species were available, it is not expected that the number of initial prairie seedlings would be greater than about 10 with this approach. This is because most species are non-prominents and hence normally have low density values.

● - initial prairie seedlings

- final basal boundaries of initial prairie seedlings

X - initial grass companion crop seedlings

O - volunteer prairie seedlings

The studies covered in his review, and in others (Whittaker and Feeny 1971; Wilson 1970), show that researchers are beginning to unravel a whole realm of allelopathic and related "competitional" relationships. These include a second and very important group - the microorganisms. Rice (1964) has shown that the different micro-floral conditions which seem to be needed for proper mineral uptake for different species, can be greatly affected by the exudates of plants already present; in his examples this seems to be a main factor in grassland succession. Finally, Clements et al (1929) pointed out the importance of traditional competition wherein one group of vascular plants physically interferes with the amount of water, light or nutrients otherwise available to another group. Since, as Clements et al. state, modification or adaptation is the usual -- if not universal -- effect of competition, we can expect rather specific plant tolerances for a particular complex of modified physical factors. As an example of a modern micro-environmental approach, Harper et al. (1965) illustrates the specificity of species preferences. These authors demonstrate several significant and differential effects of soil microtopography on the establishment of two Bromus species.

Methods

In view of the preceeding considerations, it seemed desirable to see if some perennial prairie grass would be able to hold the interspaces against invasion of serious weeds for several years while minimally suppressing the desired prairie species. This native companion crop would need several traits -- such as being early-successional and easy to propagate -- and wild rye, Elymus canadensis L., met these requirements best. A second native species was also tried to see if it might be feasible to use a normal climax grass as a companion crop. Such species would have to be quite aggressive in the initial disturbance conditions of planting, yet be slightly inferior in the intense later competition with the other late-successional prairie species. The weeds, if initially set back, should have little chance of ever regaining a foothold in spaces fully occupied by those two groups of competing plants with very similar adaptations. I chose Indian Grass (Sorghastrum nutans) whose seedlings are fairly vigorous on disturbed sides (Weaver, 1954) and whose usual occurrence as single stems or very small bunches results from its very poor tillering ability under intense competition. For comparison, oats was chosen as the conventional companion crop since it is often used that way in current prairie restoration. It had been recommended for that use quite early by Greene and Curtis (1953). Figure I presents a hypothetical pattern that suggests stocking densities for prairie species and a typical grass companion crop.

The first experiment used rows of seedlings germinated in situ and thinned to standard density, surrounded by various nurse crops (Figure II). Except for clipping, the other treatments -- fallowing, ground covering, and soil sterilizing -- represent typical alternatives to companion crops and hence can be regarded as controls. Since clipping was evaluated on each treatment in the first experiment by cutting all odd-numbered plots, replication was not part of the design. This preliminary approach was taken because a new type of question (nurse crops) was being asked while at the same time detailed examination was being made of several general aspects of early-stage prairie plant establishment. In the second experiment (plugs), there was an adjacent similarly-clipped replicate for each treatment.

Field Methods

A pair of strips on contour on a dry mesic site with a gentle northwest slope was selected in the UW Arboretum. The Fox loam soil, dominated by Poa compressa, was plowed in the fall of 1968. The soil characteristics, measured along the length of the strips chosen, varied but little as shown by pH tests, water retaining capacities and 7 profile borings. Figs. IV, V, VI in Photo Section show the site.

Experiment 1: Companion crops with seeded rows

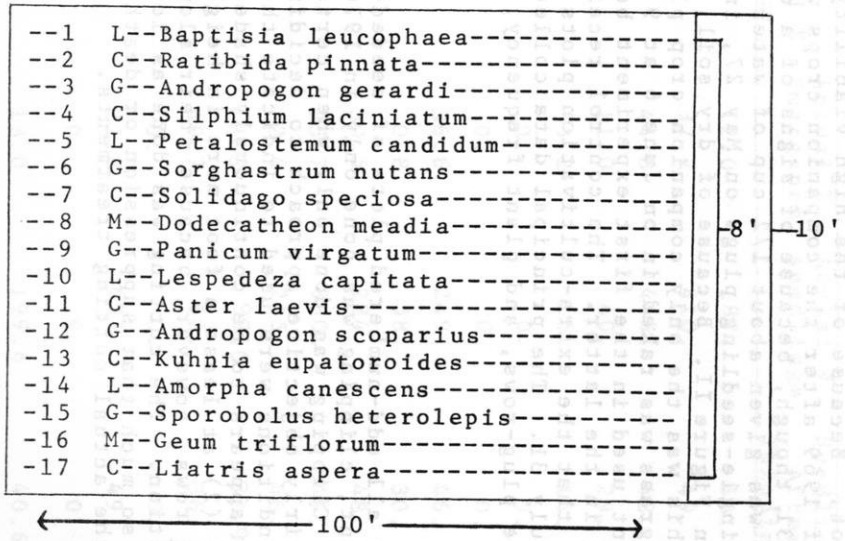
The soil was well disced and raked smooth on May 1-2, 1969. Figure II indicates the design used. The companion crops were broadcast, raked in 1/2" and rolled May 4. Stratified seeds of typical prairie species were planted, as shown in the 17 plot rows, on May 7-12, 1969. A constant number of seeds of each species was placed in the same position in each of the first 10 plots so that we had 17 mono-specific lines running across what amounted to 10 treatments once

SOIL STERILIZATION		COMPANION CROPS								NO PRAIRIE PLANTING	
Methyl Bromide clipped 1	Methyl Bromide 2	Wild Rye c.c. clipped 3	Wild Rye c.c. 4	Oats c.c. clipped 5	Oats c.c. 6	Indian G. c.c. clipped 7	Indian G. c.c. 8	Weeds "c.c." clipped 9	Weeds "c.c." 10	Weeds only clipped 11	Weeds only 12

Companion crops and seeded-rows

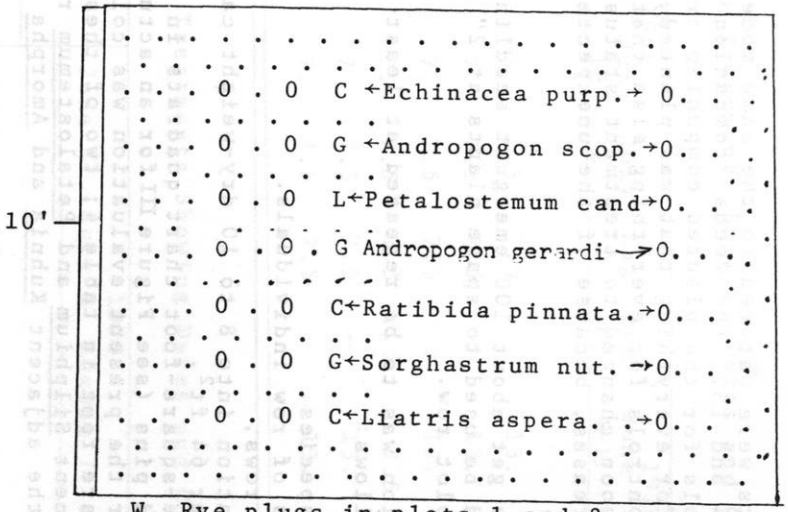
Companion crops and plug-rows

Close-up of design in treatments 1 through 10 (17 rows of seedlings)



L - legume G - grass
C - composite M - miscellaneous

Close-up of design (7 rows of 8 plugs per plot) (see text for the 3 treatments)



W. Rye plugs in plots 1 and 2

FIGURE II

Layout of the two main experiments. c.c. means Companion Crop. All plots are 10 feet square in both experiments.

Compare with figs. IV, V, VI in Photo Section and see Map Section for Arboretum location.

clipping started. All plots were watered to the same moderate degree with a fogger spray on both May 14 and 15. The weeds "companion crop" treatments, plots 9 and 10, were to be controls for the planted companion crops. The weeds-only plots were to be controls for everything that was planted, while the Methyl Bromide plots were to be controls for everything else that grew. However, the Methyl Bromide plots were soon changed to treatment status with no further interference with weed increases, because of the unexpected retardation of early prairie plant growth there.

An attempt was made to get about 100 emergent seedlings per eight-foot plot row, so that thinning could be used to space plants at 2" on the average, yielding about 48 seedlings per 8' plot row.

The main data collection was to be repeated at least once in the second season on each plot, as follows:

a. Emergence of row species.
b. Survival by counts of row individuals.
c. Average height of rows.
d. Harvest and separation into 8 to 10 dry-weight categories for all plants in the inner 64 ft^2.
e. Four complete, one-square-foot chart quadrats in late August, based on permanent field pins (see Figure III for an actual example). The main parameter for the present evaluation was collective height expressed as inches per square foot in table 4; two of these quadrats were always taken on the adjacent Silphium and Petalostemum rows and the other two always came from the adjacent Kuhnia and Amorpha rows.

Experiment 2: Companion crops with plug-rows

The soil preparation was similar to that used in the previous experiment but included a rototilling on May 27, 1969. The treatments were: (1) wild rye, (2) Indian grass and (3) extra-cultivation, each with and without clipping. The single control plot was equivalent to the weeds "c.c." of the first experiment. There were seven plots as shown in the heading of table 6. The close-up of the design for the two wild rye plots appears in Figure II. All plots had the same pattern for the desired (row) species; i.e. each of the seven species had a row of eight plugs in each plot. Because of the high viability of plugs, these were to be added in the fall of 1969 after the companion crops were well established. They were put in on July 31, though, because of signs of a die-off in the seedling bed. Each of these plugs was given about 1/2 cup of water on August 3. The wild rye had been planted by single-seedling plugs on May 27, in the low-density staggered pattern shown in Figure II. Because of dry soil, these two plots were watered that same day. This was the only companion crop planted this way in both experiments. The Indian grass was raked in on June 6 at 9,000 seeds per 100 square foot plot or 1/4 the amount used in the first experiment because germination was much higher than expected in the latter. The control received the same soil treatment as the others except that the extra-cultivation plots got an extra and thorough cultivation on July 31. The principal data collected were the survival and heights of the prairie plug-rows, and plant frequency, using circular quadrats 1/8 foot square.

Clipping

Clipping was done on all odd-numbered plots of seeded-rows in both summers. In the plug-rows experiment, clipping was done only in 1970 and applied to both plots of each treatment. Clipping was done only when certain criteria were met within a plot, using a fairly objective approach to deciding on the best cutting dates and levels. Two conditions were used to indicate the date: (1) When at least 1/2 of any plot-row appears to be continuously shaded by weeds or companion crop plants that are also (2) at least a foot more in height. An exception has made for the Amorpha canescens rows, however, because their slow growth may have been due to inadequate inoculation. The cutting was done as low as possible without injuring any row species so much that suppression or death would seem likely. Tables 1 and 2 indicate the actual cutting treatments.

Table 1: Seeded-Rows Clipping Treatments Showing Dates and Cutting Heights in Inches.

Treatment and Plot Number	1969 June 28	July 6-9	July 18	July 27	Aug 5	Aug 20	1970 June 8-13	July 7-11	No. of Cuts
Methyl-Br (1)	-	-	7.	7.5	7.5	-	13.	10.	5
Wild Rye (3)	7.	7.	7.	7.5	7.5	-	13.	11.	7
Oats (5)	7.5	7.	7.	7.5	7.5	7.5	13.	10.	8
Indian Grass (7)	7.	7.	7.	7.5	7.5	7.5	9.5	8.	8
Weeds "c.c." (9)	7.	7.	7.	7.5	7.5	-	13.	9.	7
Weeds Only (11)	-	7.	7.	7.5	7.5	-	13.	9.5	6

Table 2: Plug-rows Clipping Treatments Showing Dates and Cutting Heights in Inches.

Treatment and Plot Number	1970 June 17	July 3	August 7	Number of Cuts
Wild Rye (1,2)	13.	10.	-	2
Indian grass (3,4)	9.5	7.	4.5	3
Control (5)	9.5	-	7.	2
Extra Cultivation (6,7)	13.	-	-	1

Table 3: Seeded-Rows Species Behavior as Averages For Plots 1 to 10 in 1969.

Species	Minimum Expected % Emergence	Actual % Emergence	Actual # seedlings	Seedlings After Thinning	Height in Inches August 1, 1969
Amorpha	6.5	12.0	187.	45.	1.0
Andropogon gerardi	9.	37.2	410.	49.	9.6
A. scoparius	10.	44.8	448.	48.	4.2
Aster	15.	11.0	40.	29.	2.7
Baptisia	7.	3.2	16.	14.	2.8
Dodecatheon	10.	0.	0.	0.	-
Geum	20.	0.	0.	0.	-
Kuhnia	40.	36.6	249.	46.	3.7
Lespedeza	2.2	0.8	38.	30.	3.7
Liatris	10.	30.5	284	48.	2.3
Panicum	4.	35.7	880.	49.	9.0
Petalostemum	1.	2.4	245.	46.	2.4
Ratibida	20.	19.8	99.0	32.9	5.3
Silphium	60.	49.7	60.	36.	7.2
Solidago	20.	0.	0.	0.	-
Sorghastrum	5.	22.8	437.	49.	9.5
Sporobolus	25.	0.	0.	0.	-
Averages	15.6	18.0	199.6	40.6	4.9

Minor Experiments

Because of many prairie restoration activities in progress at the UW Arboretum in 1969 and 1970, there were several opportunities to set up simple experiments with minor additional effort. Two with great pertinence to current problems were selective sweetclover control and prairie germination trials.

Results

Experiment 1: Companion Crops with Seeded-rows

(a) Species behavior: As seen in Table 3, the greatest differences from expected emergence were in four grasses and in four species that gave no emergence at all. Since emergence of the four grass species was much higher in the wet spring than expected, they required a thinning very difficult to execute. The actual thinned number of plot-row plants was rather close to the desired 48, namely, 40.6 on the average.

(b) Treatment effects: Table 4 shows a good consistency for these row results: initial emergence; total thinned plants left; and total thinned legumes left. Table 5 shows the main measurements of serious weedy grasses, and the corresponding companion crop intensities, in culm densities.

The main evaluations at this time will be on two important groups, the row species and the serious weedy grasses (SWG). These are all perennials, and the main species of the last group are Agropyron repens, Poa compressa and Agrostis alba. Also because of the clipping complication, comparisons based on absolute values had to be kept separate for the odd and even numbered plots. In the sterilized plots, the row species have done considerably better in most measures than elsewhere. However, many plants got off to a slow start there as shown by the August 1, 3.1" average heights. Although that effect was soon lost in 1970 and the collective heights for SWG are still very low, these plots now have the highest collective height and seedling density of another serious weed, sweet clover. Because of many such unusual conditions in these plots, they will not be used for additional comparison of results in this paper. Plots 3 through 10, then, will be referred to as the regular plots.

For the regular plots, clipped wild rye (plot 3) is seen to have the highest 1969 total row species weights and a SWG weight that doesn't differ significantly from the lowest (in the clipped Indian grass plot). Similarly when the 1969-70 increase in SWG collective heights and the final values are considered together, clipped wild rye showed results that were as good as any of the regular plots except Indian grass. However, both Indian grass plots also had the poorest overall row species responses. When considering all such measures together, including survival and height for all row species, clipped wild rye definitely performed better than any other clipped regular treatment. It should be noted, though, that the unclipped wild rye was roughly equivalent in the overall SWG response to plots 6 and 10. Since dry weights should be the most reliable measure here, plot 10, the unclipped companion-crop control, was felt to have the highest SWG growth by a small amount.

Plot 8, Indian Grass, had the greatest suppressive effect on both the SWGs and the row species for the unclipped plots. However, unlike its clipped counterpart, it showed a small but definite increase in the collective height for row species between 1969 and 1970. Overall row species responses in the rest of the unclipped plots aren't strikingly different yet, except for the unusual second-season prairie legume decline seen in both oats plots. A consideration of all measures for that legume group shows that these plots have definitely the poorest response. Even in both of the Indian grass plots the legumes have done substantially better so far. The main measures used were average heights of the 4 rows involved, their total weight, and their survival values. (Survival is shown in Table 4 as total legumes left in 1969 and 1970). It does appear, however, that the negative effect extends to sweet clover as well. Examination of this fall's dry weights should verify this.

Table 4: Seeded-Rows Treatment Effects on the Row Species.

PLOT VARIABLES	TREATMENTS										
	Methyl-Br		Wild Rye		Oats		Indian Grass		Weeds "c.c."		Averages
Plot Number	1	2	3	4	5	6	7	8	9	10	
Average % emergence	17.8	17.4	17.0	18.9	18.4	18.0	18.9	17.2	18.1	18.6	18.0
Total thinned plants left in 1969	506	511	515	533	529	532	548	531	531	535	527
Total thinned legumes left in 1969	122	134	135	135	130	138	144	139	135	139	135
Total legumes up in 1970	112	143[a]	114	88	65	60	108	113	112	96	101
1 Aug., 1969 average height of all rows in inches	3.1	3.1	5.2	5.4	4.9	4.8	5.1	5.0	5.9	6.2	4.9
4 Sept., 1969 average ht. of all rows in inches	6.8	7.5	7.9	8.2	6.8	8.4	5.5	6.4	8.9	8.5	7.5
Total row dry-weight 1969 in grams	189.9	192.2	121.9	67.2	42.4	115.5	42.0[b]	40.0[b]	112.8	68.7	99.3
Collective height[c] 1969 in inches/av. sq. ft.	62.8	67.8	51.3	73.0	46.3	46.3	55.0	46.5	78.0	89.3	61.6
Collective height[c] 1970 in inches/av. sq. ft.	246.3	328.5	120.5	104.0	85.8	79.0	37.3	55.0	76.5	111.8	124.5

[a] The 1970 value is more because of summer 1969 germination.

[b] These are estimates as companion crop is mixed thoroughly with the row grasses in harvesting.

[c] Based only on the 4 forb species in the permanent quadrats.

Experiment 2: Companion Crops with Plug-rows

The main results (Table 6) are fairly self-explanatory. The analogue of the first experiment's sterilized plots, the extra-cultivation plots, behaved quite similarly; i.e., a spectacular growth of the prairie species followed by an equally spectacular increase of serious weeds in the open interspaces. This effect is seen in the considerably better growth and survival of the prairie plugs there concomitant with serious-weed category values that are equivalent to those of the control. The overall response of the row species does not vary much in the other treatments. Indian grass plots have slightly lower prairie species values than any other plots, and they exhibited a moderately high growth of serious weed groups. The wild rye plots, on the other hand, had plug-row species responses at least as good as any others (outside of the extra-cultivation plots) while exhibiting definitely the poorest serious weed growth of the whole experiment. The original (transplanted) wild rye seedlings were well tillered by June 15, 1970, with an average of 7 culms that averaged 20 inches high. This compared to an average of 1.5 culms that had somewhat smaller mean heights in both plots of the first experiment.

Minor Experiments

Only one set of experiments, that of evaluating dry over wintering as a seed treatment, will be mentioned here: The typical grass and forb species chosen gave as good or better germination values than would be expected from regular stratification. The replicate values were usually in close agreement. The most striking increase came with unscarified Amorpha canescens giving 44 and 58% and 71 and 68% in two spearate trials when only 10-15% was expected. Also a trial of wild rye gave 90 and 100% germination.

Discussion

1) In regard to specific evaluations, it should be remembered that most of the experimentation is of a preliminary nature; not all of the second year's data are evaluated here.

2) The evaluation of plant group responses was made by considering the various aspects of the main measures together, so that, for example, with SWG collective heights, a moderate increase and a high final value is felt to be worse than a large relative increase and a small final value. Also, dry-weight and survival were regarded to be better indicators of success than collective heights. Although only four of the row species are involved in collective heights, they represent a range of forb types such that their average values, as shown in Table 4, are felt to be fair indicators--of general suitability for prairie forbs.

3) The normal wild rye effect was probably only partly expressed in the seeded-rows' plots. Because of its cool season nature, about 1/3 of the stratified wild rye seeds were already germinated at planting time. Apparently the resultant shock caused a competitional setback that the wild rye never fully recovered from. Its plot height values were only equivalent to those of the Indian grass plots in midsummer; its tillering, even in open areas, was far short of the more normal amount seen in the plut-rows plots. It is felt, however, that if this early germination problem had been avoided, by using the now-tested dry overwintering treatment, the weed discouragement would have been a lot greater while the row responses would have been about average; i.e., an overall effect like that seen in the plug-rows experiment.

4) A good evaluation of the sterilized and extra-cultivation treatments would have to wait at least until the third summer. The rapid growth of the row species there may have sufficiently suppressed the abundant serious weeds, so that a rather weedless aspect, like that eventually expected from some of the regular treatments, might result. However, this possibility seems likely only in the unclipped sterilized plot that is so rank that the many, but shorter, serious weeds there may have been too shaded to be able to do much next summer. Sweet clover, at least, may be expected to be a very noticeable dominant in the other 3 plots next summer and possibly in the former also. There seems to be little chance for the slow row-species there like Amorpha canescens.

Table 5: Seeded-Rows Companion Crops and Treatment Effects on Serious Weedy Grasses.

PLOT VARIABLES	TREATMENTS										
	Methyl-Br		Wild Rye		Oats		Indian Grass		Weeds "c.c."		Averages
Plot Number	1	2	3	4	5	6	7	8	9	10	
6 July, 1969 c.c.[a] seedlings/square ft.	-	-	9.5	8.4	8.8	11.0	57.0	69.0	-	-	-
1 Sept., 1969 c.c. culms[b]/square ft.	-	-	15.0	14.0	-	-	136.0	117.0	-	-	-
1 Sept., 1970 c.c. culms[b]/square ft.	-	-	13.0	12.5	0	0	177.0	151.0	-	-	-
SWG[c] total dry weight 1969 in grams/plot	0.0	0.0	25.8	100.5	36.0	137.8	22.4	66.0	71.2	154.4	61.4
SWG collective height[b] 1969 in inches/ average square foot	0.0	0 5	170.8	284.8	143.8	115.5	109.8	99.5	139.3	308.8	137.3
SWG collective height[b] 1970 in inches/ average square foot	14.8	8.0	422.3	988.0	753.8	715.3	108.5	118.8	478.0	773.0	438.1

[a] c.c. is companion crop.

[b] based on 4 permanent, 1 foot-square quadrats per plot.

[c] SWG are serious weedy grasses.

Of course this weed problem can probably be almost eliminated, at least for sterilized sites, by using a high stocking of the desired species; i.e., on the order of 300 seedlings per square yard. However, besides the structural differences resultant from just the high initial stocking of the late-successional (desired) species, it is possible that the initial effects of drastically altering microbial relationships by sterilizing may also be long-lasting. One effect, seen only in the sterilized plots, was a great irregularity in individual row heights. Because the retarded parts of adjacent rows often occurred together, as shown in Figure V, it was felt that these patches may have been slower in getting reinoculated and thereby presented greater nutrient stress to the plants. This point was not tested, however, and factors such as a puddled bare soil surface probably made some detrimental but unknown contribution. Actually these plots seemed retarded overall until August 1969. In that month their average row-height doubled to about the average value of the whole experiment (Table 4).

5) The clipping effects seem to be best evaluated in the following year as cutting is done in the warm season when the prairie species are rapidly growing and many serious weeds are relatively dormant. The ability to replace lost foliage then will be more a function of the season than of relative importance for those two groups. Actually it is probably this differential response and better light for the slowest prairie species that accounts for the beneficial effects of clipping or shredding at the 6 to 10 inch level in the first two summers.

6) The low heights of the plug-rows, in all but the last two plots of the second experiment, illustrate the type of long-range effects to be expected from a timing handicap in entering the race for a share of the environment.

7) The striking differences in a number of measures between plot 7 and its replicate, as shown in Table 6, may relate to the fact that it is the only plot in both experiments located adjacent to a large fallowed area.

8) The artificiality of using rows was not felt to be a serious problem in making many evaluations that can be applied to regular restoration plantings, because the main type of plant interaction interfered with, that occurring between the desired species, isn't felt to be very significant for the first two years in a low-density planting. The big advantage rows give in getting measurements and counts probably balanced the disadvantages of artificiality.

9) Table 4 shows that there was a good consistency of average row initial-emergence over the ten plots. The row species individually were, for the most part, just as consistent in initial emergence. Because of this, it is felt that the method could be used without thinning for many general experiments if less seed is planted. However, for greater precision, considerable replication, thinning, or use of plugs in equal numbers would be better. Complete evaluation of any treatment would require not only considerable replication on scattered sites and in differing seasons, but also that it be done where the prairie species are planted in the usual way--i.e., a uniform broadcasting of a thoroughly mixed seed-batch of all the desired species. The impracticality of such a program, until the number of promising treatments has been lessened to a few, is obvious.

Clipping

The large overall differences in times and levels of clipping shown in Tables 1 and 2 should not be regarded as different treatments; i.e., since the same criteria were applied to all odd plots of seeded-rows, and, in 1970, to all plots of plug-rows, the actual differences in application represent effects of the previous treatments. In seeded-rows, cutting was often down to that level where considerable leaf-surface losses would start with Silphium. The other forbs were shorter and the grasses were usually able to take an even lower cut.

If recognition of immature plants of all desired species is impractical, in an actual restoration, one way to guide determination of cutting times and levels would be to use height data like those in Tables 3 and 4. Table 4 has the average height of the 13 row species per plot and Table 3 has the average height for these species over all 10 plots.

Table 6: Plug-rows Treatment Effects.

PLOT VARIABLES	TREATMENTS AND EFFECTS						
	Wild Rye		Indian Grass		Control	Extra Cultivation	
	1	2	3	4	5	6	7
c.c.[a] seedlings/square ft., June, 1969	2.2	2.2	26	25	-	-	-
c.c. culms/square ft., June, 1970	14	12	98	85	-	-	-
Quackgrass culms/square ft., June, 1970	(low)	(low)	39	26	90	35	8
Quackgrass frequency[b] (%) June, 1970	25	21	83	74	98	53	19
Poa spp. frequency, June, 1970	29	19	26	56	50	83	65
SWG[c] sum frequency, June, 1970	54	40	109	130	148	136	83
SW[d] sum frequency, June, 1970	117	108	128	173	191	232	181
Surviving row plugs, June, 1970	36	28	26	24	27	42	38
Average plug-row height (inches) June, 1970	4.2	3.7	4.0	3.4	4.3	12.0	16.6
Average % of incoming light[e], 2 July, 1970	71	58	16	21	43	25	15

[a] c.c. is companion crop.

[b] From 1/8 square foot quadrats.

[c] SWG are all serious weedy grasses

[d] SW are all the the serious weeds treated collectively; i.e., includes dicots, especially the vigorous biennials, Sweet Clover (Melilotus spp.)and Wild Parsnip (Pastinaca sativa).

[e] Readings taken at 4 inches above the soil.

The Nature of Companion Crops

The differences of opinion as to the effect of companion crops probably result from conclusions based on different situations or some misunderstanding of the establishment processes of prairie-like species. In high density plantings, the initial desired-species seedlings themselves act as a companion crop; additional plants of any kind would further restrict the desired species and have little additional effect on weeds.

In numerous prairie competition trials, Clements, et al. (1929) present evidence on the nature of competition indicating that the timing and intensity of the affecting factors can often be more important than the species involved. For example, in some Indian grass versus needlegrass trials, the needlegrass was expected to gain complete dominance over the other because of better adaptation to the site and earlier spring growth. While the first culture did exactly as expected, the second saw Indian grass completely eliminate the needlegrass by the second fall. They felt the latter outcome resulted from the Indian grass getting the jump on absorption and also said that in dense seedling stands generally, differences of only 1 or 2 inches of root length resulting from but 1 or 2 days growth can easily be the deciding factor. It is not surprising, then, that entirely different results can be obtained from not providing the proper intensity of the various factors at the right time even if the same companion species is used.

Certain companion crop techniques are sufficiently worked out in some areas of forage establishment to be easy to apply properly. Barring herbicide use, there is little question as to their value in such situations. Smith (1969) emphatically advised the use of a grain companion crop for alfalfa and clover seedings. While such advice is based partly on the harvest value of the companion crop, he also asserted that the competition to the slow forage seedlings would be less from the grain than from the weeds that would result without their use. Smith had found (1962) that there is a tendency for the weight of the combined category of weeds and companion crop to be constant. For example, one experiment showed that this category stayed at about 4,400 pounds per acre for six levels of increasing oats companion- crop intensity. The weeds component went progressively down from 2,102 to 313 pounds, while the agronomic legumes showed no significantly different responses.

The weed-increase problem after the death of the short-lived oats in the seeded-rows experiment wasn't too surprising, but the drastic negative effect on all four row-legumes was. While the composites as a group responded somewhat better, being about as poor as in the Indian grass plots the first year, the row grasses did quite well. I don't think these results are due to a greater shading of the slower forbs because the oats quickly shot up above all of the row species and stayed above until they died in mid July 1969. If there is really such a differential family response, then the cause may be of an allelopathic nature. Christiansen (1970) noticed a stunting effect on both prairie plants and weeds from an oats companion crop, that likewise seemed to be allelopathic.

The advantages of using a suitable native companion crop are (1) a much longer reign of the simple weed displacement effect shown by just any species, including oats, and (2) a probable minimum of serious allelopathic effects on the desired species that normally succeed it in nature. Asituation marked by relatively large and well-lighted spaces between the companion crop plants but where all of the soil is well supplied with fine roots in the first few feet, may represent still other features of the normal micro-environment favorable for increases of the late-successional species, yet unfavorable for the shallow-rooted serious weeds--especially if the companion crop is also a cool-season species. The occurrance of Wild Rye (*Elymus canadensis*) is often restricted on natural uplands, except, as Weaver (1954) says, it is common on gopher mounds and other bare spots. It also intercepts relatively little light and has a dense root system that is only about 2 feet deep but almost 4 feet in diameter (Weaver 1926; Clements et al., 1929). Hence it is physically much different than the more climax-like grasses of its communities. The micro-environment it helps to complete on such sites may well be the type of one that prairie seedlings have become adapted to start in. It's not likely that the rye would have any direct beneficial effects on those plants, but since it has often preceeded them, it is also not likely to have unfavorable effects.

The normal process on many sites may be that wild rye as a first perennial on a denuded area is first invaded by late-successional grass seedlings, which may become moderate-sized but rather well-spaced clumps by the time the more slowly dispersed "climax" forbs get started. However, the latter may be able to get established in the wild rye matrix only at points several inches or more away from rye's late-successional grass clumps (after Blake 1935). This is probably true even if there are new but very restricted surface disturbances from animal scratching, that may additionally be required. Although the climax grasses have rather vertical roots that seem to seldom extend to even a foot from the base of the plant (Weaver 1926), they are quite dense to depths exceeding 4 feet. Weaver (1954) found that prairie forb seedlings can send down a 2 to 3 foot taproot in the first year even th ough their tops may be very insignificant. Furthermore, he showed that many mature forbs do most of their absorbing and branching below 2 to 4 feet, or below the depth of wild-rye roots. The forb seedlings may only be able to "punch" through the dense grass roots to maintain a proper transpirational balance at a certain minimum size clump interspace among the climax grasses. Under intense competition it seems reasonable that this size would vary for many species. The specificity of this type of relationship is suggested by work where only one species, sweet clover, was planted in bluegrass sod cut-outs. Caruso (1970) found differences significant at the .01 level for its survival in four cut-out sizes that ranged from 0.5 to 3.0 cm.

Considering the multitude of structural patterns possible with alteration of the normal processes of succession by the very act of planting, the importance of minimally restricting such processes can be seen; i.e., relationships such as clump size and spacing, that are relatively static once the space is fully occupied by late-successional plants, probably do much to determine the pattern of future plant locations for a long time afterward. While it is relatively easy to establish a prairie species by planting, it seems to take a long time for its plants to be eliminated even if out of place (Cottam and Wilson, 1966). It may well be that the wild-rye pattern of a few large and regularly spaced plants, as seen in the plug-rows experiment, is also better than the other extreme seen in seeded-rows. However, the former condition is not as easy to get with seedings and appears to be nowhere near as important as it is with the late-successional species. The desired species, started at the same time as the wild rye companion crop, are adapted to increase in such a situation while wild rye decreases. That phenomenon is indicated in Table 5 by the decline in rye culm density since 1969, while the late-successional Indian grass companion crop increased.

Therefore Indian grass (Sorghastrum nutans) seems in this study to be an unsuitable companion for even artificial restorations that start only with late-successional species. It seems that in order to keep weeds down, a very high initial seedling-density, as was obtained in the seeded-rows experiment, is needed. The result there was a stunting of all plants that may last a long time. This problem is illustrated by comparing Table 5 with Table 6 where even a moderately high density of about 25/square foot, in the plug-row plots, seemed insufficient for good weed discouragement. Switchgrass (Panicum virgatum) might be a more suitable species for that type of restoration. In the seeded-rows strip, it was less aggressive and intercepted less light than the Indian Grass and was hurt much more by clipping than the other three row grasses. Robocker (1951) found, for the dominant prairie grasses, that hay-stage clipping hurt only switchgrass considerably. This sort of vulnerability, which it shares with the wild rye, is valuable because it allows the scales of competition to be tipped, by a properly timed low cut, in favor of the desired species if they are suppressed. Drastic clipping of this sort is done after the disturbance effects from planting, that promote most weed increases, have waned substantially.

Switchgrass might even be suitable to try as a partial or complete substitute for wild rye in natural-like restorations that start with low densities of the desired, late-successional species. This is not only because of its competitional traits, but also because its seed is easy to handle. However, since it may persist as an important plant and because it is known to be ecotypically differentiated, some qualifications will be made. Porter (1966) showed not only that there is a genetic basis for the differences between an upland and a lowland switchgrass population, but also that 18 morphological characters differed at the .01 level. One character is much greater height in the lowland strain. Such a strain certainly wouldn't be expected to provide the type of micro-environment that a mixture of the proper upland associates is adapted to increase in. Actually the requirement that

the seed be from an environment like the planting site, should present little extra difficulty for natural-like restorations, since all seed of the desired species should be so obtained anyway. This is because many prairie species have proven ecotypes and because the resultant differences, when assembled into the micro-environmental complex, no doubt present a rather specific guide for many processes of plant dynamics. This goes beyond just morphological differences. For example, the use of earlier-growing southern ecotypes in the north, will undoubtedly adversly affect the early flowering forbs there, by providing a competition the latter never before had to face.

Certain grasses other than switchgrass seem suitable for further experimental trials, especially in different areas. These include Sporobolus asper, Muhlenbergia spp.,Aristida spp. and Panicum oligosanthes.[1]

Some Structural Traits and Expected Succession

For moderately-mature, natural prairie vegetation, at least, it seems safe to say that some basic structural relationships are normally expressed if there are: high forb stem aggregations; very high grass culm aggregations; fairly diverse soil-surface micro-environments (resultant partly from first two relationships), and a high per-plant flowering rate. In restoration, a single condition such as forb aggregation might be usable as a rough determinant of the existence of some minimum of the other basic relationships. An average of say five stems per forb plant might be indicative of the stage when a restoration can be considered roughly equivalent to a very young prairie. Using this criterion in the seeded-rows experiment, and general knowledge of prairie invasion rates from Curtis (1959), it is reasonable to expect a reasonable facsimile of a young prairie to be obtained by 5 to 10 years on a dry-mesic site. This is the natural-like approach, as exemplified by Figure I. The four forbs in the chart quadrats generally have increased their stem/plant ratios in the first two years to 1.5 except in the two Indian grass plots where they actually decreased in the second year to 1.1.

It seems reasonable to assume that a high initial density of late-successional plants will increase forb mortality, retard forb/stem ratios, and greatly restrict forb volunteering. If normal forb occupancy can occur at all, it will probably be delayed until there is a considerable aggregation of grass culms. One way to describe the structural conditions that seem important here is by the combined values of Blackman's coefficient of dispersion ($s^2/\bar{x}$) and density. The following are from 16 contiguous sub-quadrats inside of 1-foot-square quadrats for $s^2/\bar{x}$ and density per square foot respectively: 6. and 20. for the middle square foot from the mid-successional pattern seen in Figure I ; 6.3 and 75. adapted from a square foot for one of Weaver's (1968) chart quadrats from late-successional, bunch-grass prairie; 3.4 and 136. in cut Indian grass (plot 7) in 1969; and 4.4 and 177. in cut Indian grass in 1970. If a stand becomes essentially "closed" for forb increases somewhere between the first two conditions (pairs of numbers) described, it can be seen that the Indian grass quadrats may never reach such a suitable state unless a large die-off occurs. Since this could probably occur only after several years at best, and after considerable loss of original forb plants, the normal forb occupancy may be quite delayed if indeed it ever occurs in this century.[1]

The fairly high legume survival shown in Table 4 for the Indian grass plots suggests a very interesting possibility which may have co-adaptational significance. The legumes here have responded relatively much better than the composites compared to other plots. Although their composite dry weights in 1970 were only about 1/6 of those in the oats plots, their legume weights were then about the same. However, even the legumes seem too stunted to have a very good survival in the next several years. The competitional behavior of late-successional species in general, when planted densely, will probably be similar to that just seen for Indian grass except where their dominance can easily be decreased as may be possible with switchgrass by proper clipping.

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[1] Ed. Note: Certain prairie forbs alone or with wild rye might also be tried as precursors or companion crops for late-successional prairie grasses. Although Arboretum prairies rich in grass establishment seem to discourage forbs, the reverse situation might not discourage grasses and might lead to better forb percentages through survival into the climax grass stage.

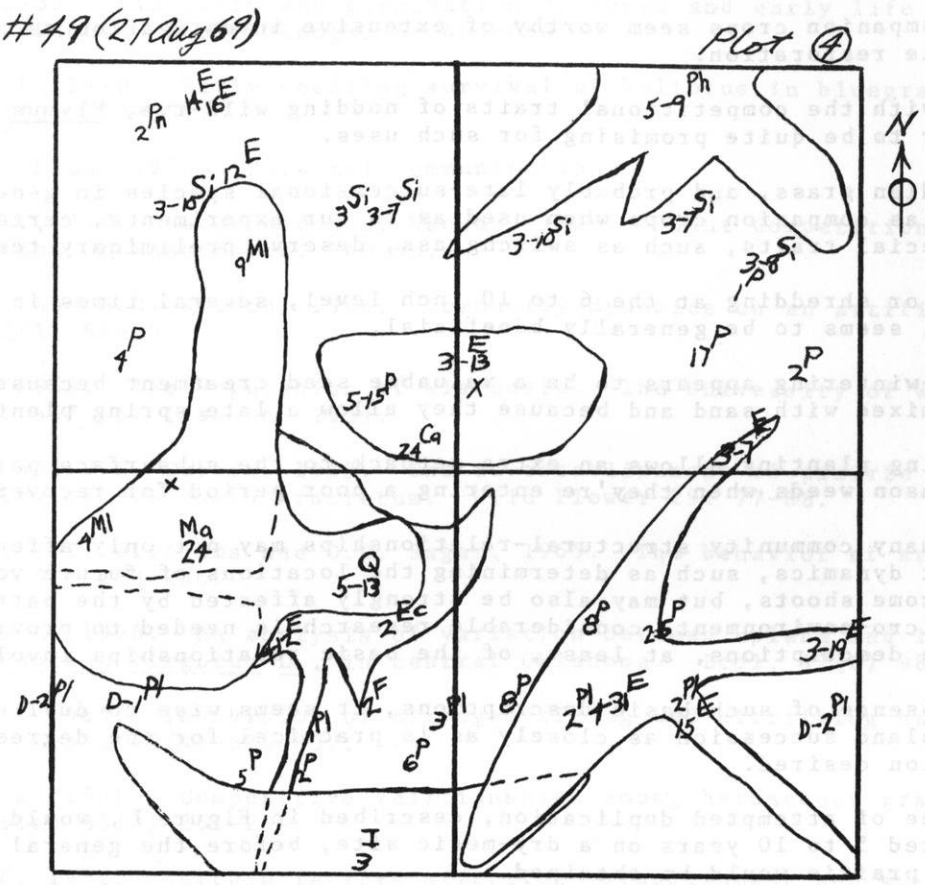

FIGURE III

A 1 foot square chart quadrat from the unclipped wild-rye plot. The number before the dash indicates the number of stems while the second number is their average height. The (stems x average height) values were summed to give collective heights; i.e., the total inches of stem or culm for each species in the square foot. The boundaries indicate the appreciable plant cover in the first year and correspond to symbols of single species groups marked in red in the field.

E = Elymus Pl = Petalostemum P = Poa Si = Silphium

Conclusions

1) Native companion crops seem worthy of extensive investigation as a method of refining prairie restoration.

2) Species with the competitional traits of nodding wild-rye, Elymus canadensis, appear to be quite promising for such uses.

3) While Indian grass, and probably late-successional species in general, show less promise as companion crops when used as in our experiments, certain species having special traits, such as switchgrass, deserve preliminary testing.

4) Clipping or shredding at the 6 to 10 inch level, several times in the first two summers, seems to be generally beneficial.

5) Dry over-wintering appears to be a valuable seed treatment because the seeds needn't be mixed with sand and because they allow a late spring planting.

6) Late spring planting allows an extra setback to the subsurface parts of perennial cool-season weeds when they're entering a poor period for recovery.

7) Because many community structural-relationships may not only affect processes of plant dynamics, such as determining the locations of future volunteer seedlings and rhizome shoots, but may also be strongly affected by the particular type of initial micro-environment, considerable research is needed to provide rough quantitative descriptions, at least, of the basic relationships involved.

8) In the absence of such basic descriptions, it seems wise to duplicate the processes of grassland succession as closely as is practical for the degree of community simulation desired.

9) The degree of attempted duplication, described in Figure I , would expectedly require an estimated 5 to 10 years on a dry-mesic site, before the general appearance of a natural prairie would be obtained.

10) While the speedy type of restoration, using high initial densities of the desired species, may look like a prairie at a distance in only 2 or 3 years, it may require decades to attain many of the characteristics obtained by the former method in only 5 to 10 years.

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EFFECT OF VARIETY CHOICE ON STAND ESTABLISHMENT OF NATIVE GRASSES IN PRAIRIE RESTORATIONS

By

Jim Wilson

Wilson Seed Farms, Polk, Nebraska

For years my wife and I have been raising native grass seed -- switchgrass, Indiangrass, big and little bluestem, sideoats grama and others -- and selling it to Great Plains farmers and ranchers for livestock and conservation use. Our clients cooperate with us in a lively experiment and education program. With their help, we have learned to get good grass stands quickly with little cost and effort.

About ten years ago, we began getting inquiries from a strange new breed in the midwestern and eastern states -- botanists, biologists, naturalists, park superintendents, arboretum directors, landscape architects, wildlife lovers, camp directors, and just plain folks -- who didn't even ask how many pounds of beef per acre they could get from native grass. They wanted it for "people" pasture!

At first I answered every inquiry with a three or four page personal information letter on native grass planting. As the trickle of inquiries swelled to a stream, I mimeographed the information and sent out hundreds of copies.

Great Oaks from Little Acorns

For years it was like talking into empty space.

Finally we began getting seed orders -- a teaspoonful of this, a tablespoonful of that. It was a great-day-in-the-morning when we got an urgent telegram from the biology department of a midsest university asking about seed "for an extensive series of experimental plots. Kindly quote prices. Please rush."

I wrote a long letter, I quoted prices -- and I rushed. A few days later came the order -- seven varieties, $7.56. It cost that much to sack it up and do the bookkeeping, but two years later the university planted 50 acres.

Today almost a fourth of our native grass seed sales are for "people pasture" of one kind or another. I don't know if all these qualify as "prairie restorations" or not. I'm not exactly sure what a "prairie restoration" is. If the planting of tall and mid-height prairie grasses for livestock and conservation use qualifies, there are millions of acres of prairie restorations in the central and eastern Great Plains. Here, native grass planting is big business and a well-developed art.

What is a "Prairie Restoration"?

About 25,000 acres of native grass has been planted on wildlife refuges and wetlands in the prairie states by the Fish and Wildlife Service and state game commissions. Are these "prairie restorations"? I would say no.

Then there are the seedings that have been made as a labor of love, for aesthetic, scientific, recreational, historical and landscape values. "Soul" plantings, you might say.

These are truly prairie restorations, because those who plant them set out deliberately to "restore the prairie." Some have gone to great pains to approximate the original plant communities by including wildflowers and minor grasses. A few were planted long ago, before the Wilson Seed Farms came on the scene. We've supplied seed for well over a hundred, totalling perhaps 3,000 acres. There are probably many more.

Except for the national wildlife refuges, the Forest Preserve District of Cook County (Illinois) has the largest prairie restoration I know of east of the Missouri -- about 220 acres, within sight of the Chicago Loop. Dr. W.T. McElhinney, of Covington, Kentucky, is probably second, with almost 200 acres on his farm in the limestone hills along the Ohio River.

All God's Children Got Pastures

Many pioneer souls, born too late into an uncongenial century, satisfy defined and undefined longings in the possession of a little island of planted prairie on the fringe of megalopolis. A New York stockbroker with a passion for little bluestem has 20 acres of it, 40 miles up the Hudson from the rat-race of Manhattan.

No Midwest college or university is complete nowadays without a piece of prairie, virgin or restored, for its botany and biology students to root around in. The roll includes Grinnell, Cornell, Luther, Knox, Iowa State, Southern Illinois University, Principia, Notre Dame, Purdue, Universities of Illinois, Michigan, Wisconsin, South Dakota State, and many more.

Arboretum botanical gardens and nature centers everywhere are sprouting mini-prairies. The Morton Arboretum and Boerner Botanical Gardens are outstanding. Park departments of Peoria, Racine, Milwaukee and other cities plant native grass so pavement-pounders can recharge their depleted batteries by contact with the spirit of the prairie. Schools plant outdoor prairie classrooms -- the Scatter-good school in Iowa, Upper Principia in St. Louis, the Alpine Center of the Davenport Public Schools, where handicapped children can touch and marvel and dream.

Prairie restorations form a living stage-set for historical attractions like South Dakota's Pioneer Village, Homestead National Monument, and the Stuhr Museum of the Prairie Pioneer, with its 160 acres of lovely tall grass in the Valley of the Platte.

Even Profit People Plant People Pasture!

Architects with concern for people as well as production dream up aesthetically pleasing industrial buildings and set them in a soul-soothing ocean of prairie grasses. The Salsbury Laboratories of Charles City, Ia., planted 42 rolling acres to big and little bluestem, sideoats grama, western wheatgrass, switch and Indian grasses this summer, as a setting for what is said to be one of the most beautiful industrial plants in the nation. All these prairie-planters, like farmers, ranchers and conservationists farther west, have learned that good native grass stands don't happen automatically!

Unlike brome, orchard, and other introduced grasses, the natives don't grow up the first year -- they grow down. Centuries of experience with periodic droughts have taught them not to flaunt themselves above-ground till they're rooted deep enough to survive. Because most are warm-season grasses -- again unlike brome and orchard -- you can't plant them to sprout in the fall after the weeds have finished their growth. The seed must be in the ground early enough to sprout and establish a stand before cool weather comes. The slow-growing, needle-thin seedlings have to fight the foxtail, barnyard grass, quackgrass and pigweed all the way. A first-year native grass seeding is, as one farmer said, "the damndest mess of weeds I ever had on the place!

When we restore cultivated lands directly to native grass, we defy Nature. For thousands of years before the white man came to the prairies with his plow and European weed seed, these grasses were self-selecting to propagate themselves on undisturbed soil. Who knows how many years of intermediate plant succession it would take for Nature to prepare an abandoned cornfield for the spontaneous return of the climax prairie? And, who knows what those native plant successions were? They've been overwhelmed by barbaric foreign weeds.

Abominable Immigrants

Vast areas of Europe and Asia have been under cultivation for thousands of years. All this time, these weeds -- foxtail, barnyard grass, mare's tail and the rest -- have been self-selecting to propagate themselves on disturbed soil, developing incredible seedling vigor, growth potential, and ability to capitalize on the mysterious soil changes caused by cultivation. The seed hitch-hiked to the American prairies almost simultaneously with the coming of the plow. You know the rest.

These Eurasian annual weeds, almost unknown to my homesteading grandfather, have become the grain farmer's most horrible nightmare. They are, by all odds, the toughest problem facing the "prairie restorationist".

My informative reprints, HOW TO GET A GOOD STAND OF GRASS, and PLANTING NATIVE GRASS FOR PEOPLE PASTURE, contain many tips on how to cope with weeds; you may have these on request. However, I wrote them before I, or anyone, fully realized the tremendous influence of variety choice on the ability of the prairie grasses to overcome these savage foreign invaders and establish a stand.

Many ranchers who have been around grass all their lives still think switchgrass is just switchgrass, big bluestem just big bluestem, and so on. Far from it. Two varieites or strains of the same kind of native warm-season grass, planted at the same location under the same conditions, can very as much as 600% in vegetative growth, with a corresponding difference in seedling vigor and ability to crowd out weeds.

All other things being equal, the farther north you move a variety of native grass from where it originated (not from where the seed was grown -- a Negro couple in Alaska won't have Eskimo children! -- but from where the variety originated), the earlier it will start growth, the faster and bigger it will grow, the later it will mature, and the more aggressive it will be, in comparison with local varieties of the same kind of grass -- until it reaches the point of winter injury. And visa versa.

It's a Wise Grass that Knows its Own Father

This is why variety choice is so important to prairie-planters with weed problems -- and that includes all of us.

In the early days of grass-planting, when all the seed was from the wild native harvest, you knew its characteristics if you knew where it came from. But so much land has been planted with seed from a distance that when you buy "common" seed today, you don't know where the strain itself may have originated.

However, the Soil Conservation Service and the state experiment stations have developed several improved varieties of each of the major prairie grasses, adapted to different latitudes. From south to north you find, for example: Caddo, Blackwell, Pathfinder, and Nebraska 28 Switchgrass; Kaw, Pawnee, Champ, and S.D. 27 Big Bluestem; Tejas, Cheyenne, Nebr. 54, and Holt Indiangrass; Vaughn, El Reno, Trailway, and Butte Sideoats Grama; Pastura, Aldous, Blaze, and NB. 130 Little Bluestem, and so on. There are also improved varieites of some of the minor grasses, and more are in the making.

The genetic characteristics of each variety are preserved from year to year by strict rules of certification. To be sure of what you're getting, buy certified seed, if available. It costs a little more, but it's worth it.

What is "Locally Adapted"?

Years ago, much native grass seed from the wild southwest harvest was sold in the central and northern Plains. It winter-killed badly. Experiment stations became very conservative, and coined the slogan, "Plant only locally adapted seed." That is, plant each variety, or strain, in the general area where it originated.

However, we've found that these grasses compete with weeds much more successfully and establish themselves much quicker if they're moved a reasonable distance north of where they originated.

For example, at the Wilson Seed Farms in east central Nebraska, when newly seeded Nebr. 28 Switch is two inches tall, Blackwell Switch is about four inches tall and sending out three or four rhizomes. At the Stuhr Museum, near Grand Island, Nebraska, Blackwell Switch was the only grass that established itself the first year in competition with the foxtail and wild mustard. It originated at least 200 miles farther south than any of the other varieites in the mixture.

Foxtail and barnyard grass are always a problem in our Butte Sideoats and Holt Indiangrass seed production fields, but never in our Trailway Sideoats and Nebr. 54 Indiangrass.

How far north can you move a native grass from its place of origin without fear of winter damage?

Ask the Man Who's Tried It

It depends on the site and the kind of grass. All kinds will maintain themselves 50 to 75 miles farther north on level, fertile "crop-type" land than on exposed, eroded hills and bleak range lands. From our experience so far, it appears that switchgrass, Indiangrass and sideoats grama can be moved farther north than the bluestems, but all can be moved farther north than we used to think possible.

"At the Plant Center at Bismarck (N. Dak.)," says John McDermand, SCS Plant Materials Specialist, "we have had no winter injury so far on Nebraska 28 Switchgrass, Holt Indiangrass, or Butte or Pierre Sideoats Grama. But we've had poor luck with Champ Big Bluestem in northern South Dakota."

The Arrowwood National Wildlife Refuge, in central South Dakota, has planted Holt Indian and Nebr. 28 Switch successfully for several years, according to the manager, Arnold Kruse.

Brookings, S. Dak., grass breeder James Ross says: "The winter-hardiness, in this area, of southern varieties is often quite suprising."

James Baird, former Montana SCS man, writes, "Our farmers bought native grass seed many times from Nebraska. It seemed well adapted."

Native grasses can be moved even farther north as they are also moved east into rising isothermal lines. They should never be moved south, except slightly as they are moved west into higher altitudes and a colder, drier climate. The safe northern limit for Kaw Big Bluestem in western Nebraska is about 40° 30', in eastern Nebraska 42°. Cliff Williams, of the SCS Plant Center at Big Flats, New York says, "We know Kaw Big Bluestem and Blackwell Switchgrass are winter-hardy north of Utica." Utica is on the 43rd parallel.

Heaviest Producers Compete Best

The amount of forage a variety will produce is a good indication of its relative aggressiveness and ability to compete with weeds, compared to other varieties of the same kind of grass. In Harlan Co., southern Nebraska, in 1969, the SCS made clip tests on trial plantings of 18 varieties of 5 kinds of native grass originating from northern Oklahoma to North Dakota. Without exception, the most southerly varieties produced the most forage, the most northerly the least.

Of five varieties of sideoats grama of New Mexico to North Dakota origin, all planted in a Lincoln, Nebraska,greenhouse at the same time, all receiving the same amount of light, water and fertility, the most southerly produced by far the most forage, the most northerly by far the least, with the others ranged between in order of their origin.

It would be impossible to set exact limits of winter-hardiness for all varieties under all conditions clear across the country. However, we can arrive at fairly reliable approximations from the scores of reports from both professionals and non-professionals who have been planting different varieties of native grass for years.

The accompanying maps show what I believe to be the belts of best adaptation for the improved varieties of the five main species of prairie grasses, from the over-all standpoint of forage production, winter-hardiness and maximum competitiveness against weeds. These belts are subject to revision as we learn more and as new varieties are released, so if you find I am wrong at any point, please let me know.

Wild-harvest seed of those native grasses of which no improved varieties have been developed can usually be moved up to 350 miles north, if the seed was harvested from virgin prairie. If it was harvested from a stand planted with seed of unknown

origin, the ripe-seed date will give you a clue as to how far north you can safely push it. A native grass should maintain itself permanently on a site if it will mature seed two years out of five.

"No Single Thing Abides, but All Things Flow"

We know, of course, that when a grass variety is moved from its place of origin to a different environment, natural selection starts working. In the belts of adaptation I have suggested, the transplanted varieties should maintain essentially their original characteristics for many years. Eventually, with the passage of time, they will become more and more like the indigenous local varieties and strains. If they've been moved north, they will get smaller, less luxuriant, earlier maturing, more content with a colder climate, shorter growing season and different day-length. And there will be other subtle changes as the less well-adapted individuals fall by the wayside. Maybe in 50 years, maybe not for 500 or more. Nobody knows, at this point.

Long before this happens, the original vegetative aggressiveness of the transplanted variety will have served its purpose, the Eurasian devil-weeds will have been vanquished, and you will have a lovely stand of grass.

If you're an ecological purist and what you wanted was a selection of the ecotypes Nature originally designed for the site, be patient. If you don't live to see them, your great grandson may. Most native grass varieties have a comparatively broad genetic base, and so far as I know, the principle of natural selection has never been repealed. In the meantime, from the practical standpoint, grass makes better people-pasture than weeds!

APPENDIX

Varietal Adaptation Maps follow for: Big Bluestem, Indiangrass, Switchgrass, Little Bluestem, and Sideoats Grama.

These maps are strictly tentative and subject to revision as we learn more and as new varieties are developed. Belts of adaptation are approximate, and there is considerable overlapping of varieties.

Since we have only scattered reports from many parts of the Middle West and the East, these suggested belts of adaptation are partly based on the eastward extension of lines of average annual minimum temperature from the regions of known adaptation. Local extremes of altitude must also be considered in the selection of varieties.

Don't push any variety north of its belt of adaptation, as shown, except on an experimental basis. If you observe any winter injury, we would appreciate a report.

Some of the numbered strains are still under test by the Soil Conservation Service, and seed is not yet available commercially. Hundreds of accessions are under observation by the SCS and state experiment stations, and many new varieites of both major and minor grasses will emerge in the next several years.

The general principle -- that native grass varieties moved north are more vigorous, competitive and productive than local varieties of the same kind of grass (up to their limit of winter-hardiness) -- is subject to three qualifications:

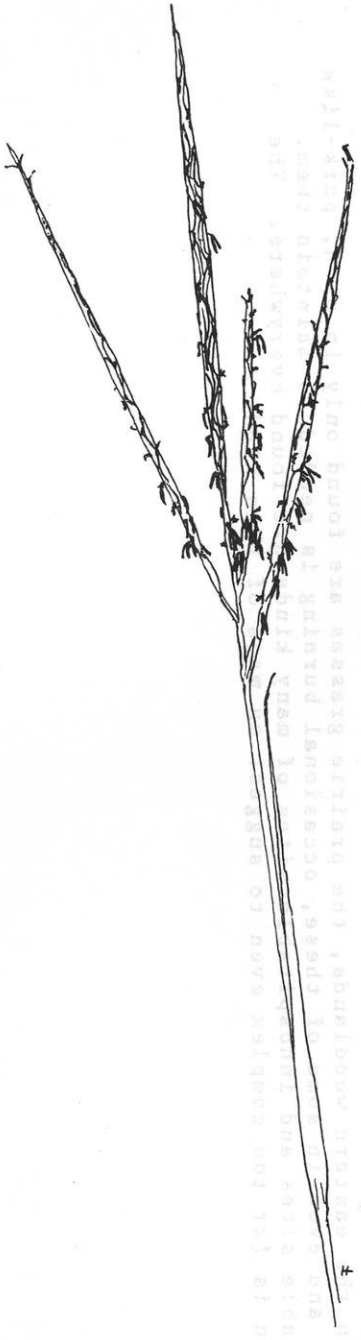
1. With grasses, as with people, individuals and groups of individuals vary, even in the same environment. A mediocre accession or selection moved north won't necessarily surpass a good local strain.

2. Different strains are adapted to different environments -- one to upland, another to lowland, etc. A strain moved north into an uncongenial environment can be disappointing. However, most improved varieties have a broad genetic base, enabling them to adapt to a wide range of environments.

3. Small arid-land varieties from the extreme western Great Plains, moved north and east into higher-rainfall territory, will probably not have the growth potential to surpass good local varieties. Most of the high-growth varieties presently available were developed under 20" to 35" average annual rainfall. In time, if native grasses are accepted on a large scale for pasture farther east, it's possible that varieties with still higher growth potential will be developed for that region. Although native grasses are becoming increasingly popular for landscaping, wildlife cover and recreational areas in the middle western and eastern states, they're still experimental for livestock use east of the 95th meridian.

In the western Great Plains, adaptation of the tall grasses -- and to an extent, the mid-heights also -- is limited to swales, ravines, and other favorable sites receiving extra moisture.

In the eastern woodlands, the prairie grasses are found only in open, park-like areas, and even in some of these, occasional burning is needed to maintain them. Hospitable sites and inhospitable sites of many kinds are found everywhere. The pattern is far too complex even to suggest on maps of this kind.



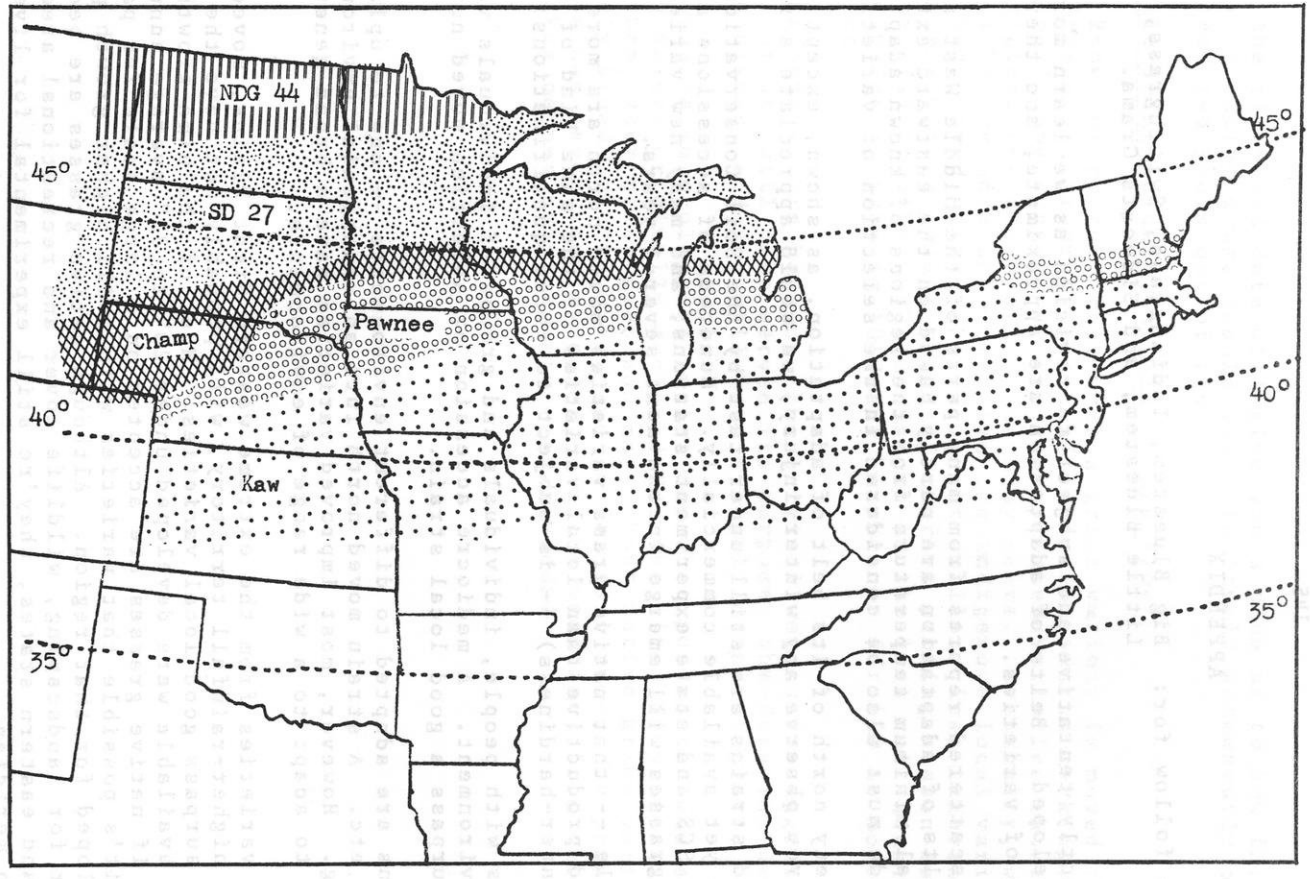


FIGURE I
BIG BLUESTEM

Nutritious, palatable warm-season tall grass, widely adaptable in mixtures. Good varieties for central latitudes. NDG 44 and SD 27 still experimental. New varieties needed to supplement and replace Kaw farther south. Champ is a "big blue-sand blue synthetic", well-adapted to sandy land, on which it is virtually interchangeable with Garden Sand Bluestem. Several Old World bluestems have been successfully introduced into Texas.

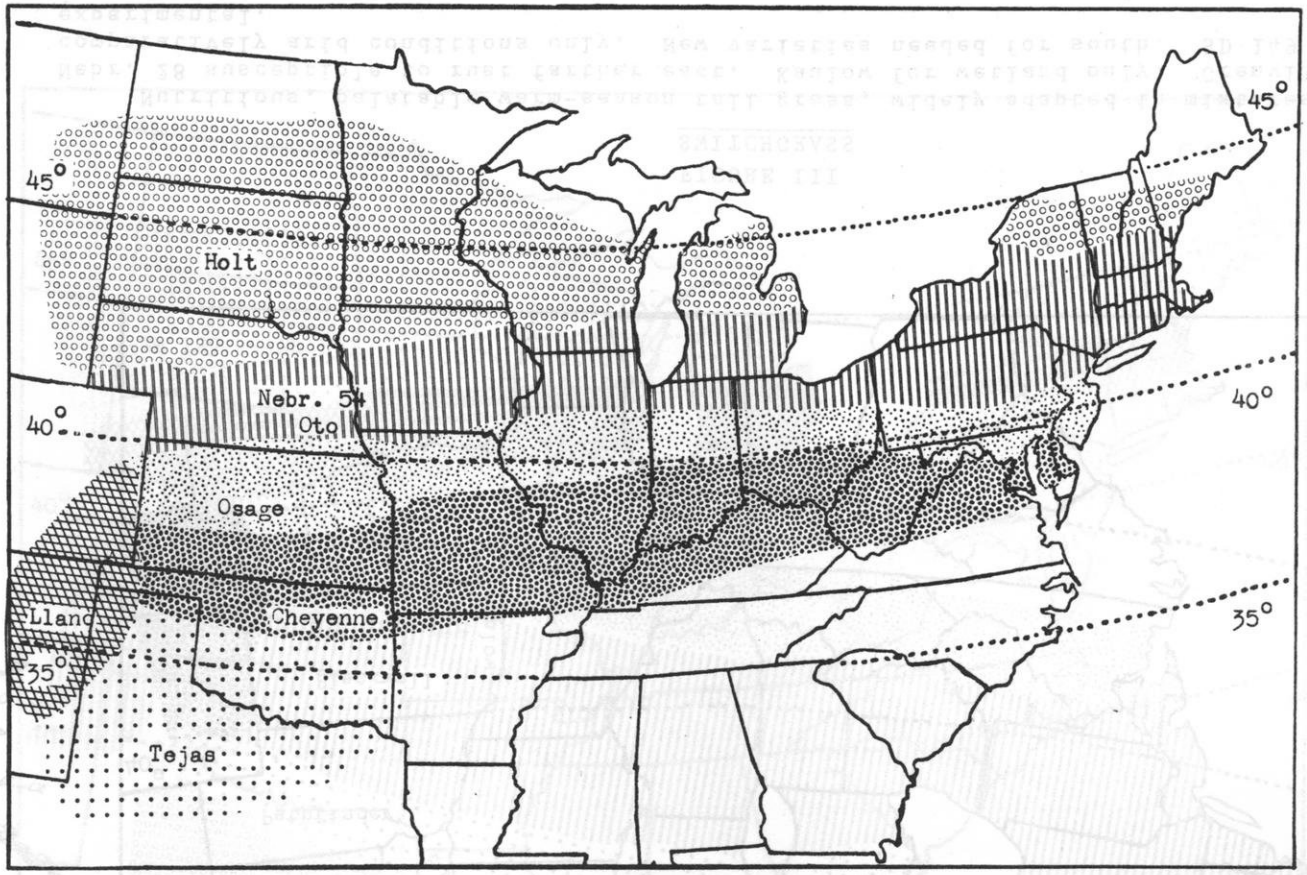


FIGURE II
INDIANGRASS

Nutritious, palatable warm-season tall grass, widely adapted in mixtures. Good varieties for central latitudes. New varieties needed for extreme north and extreme south.

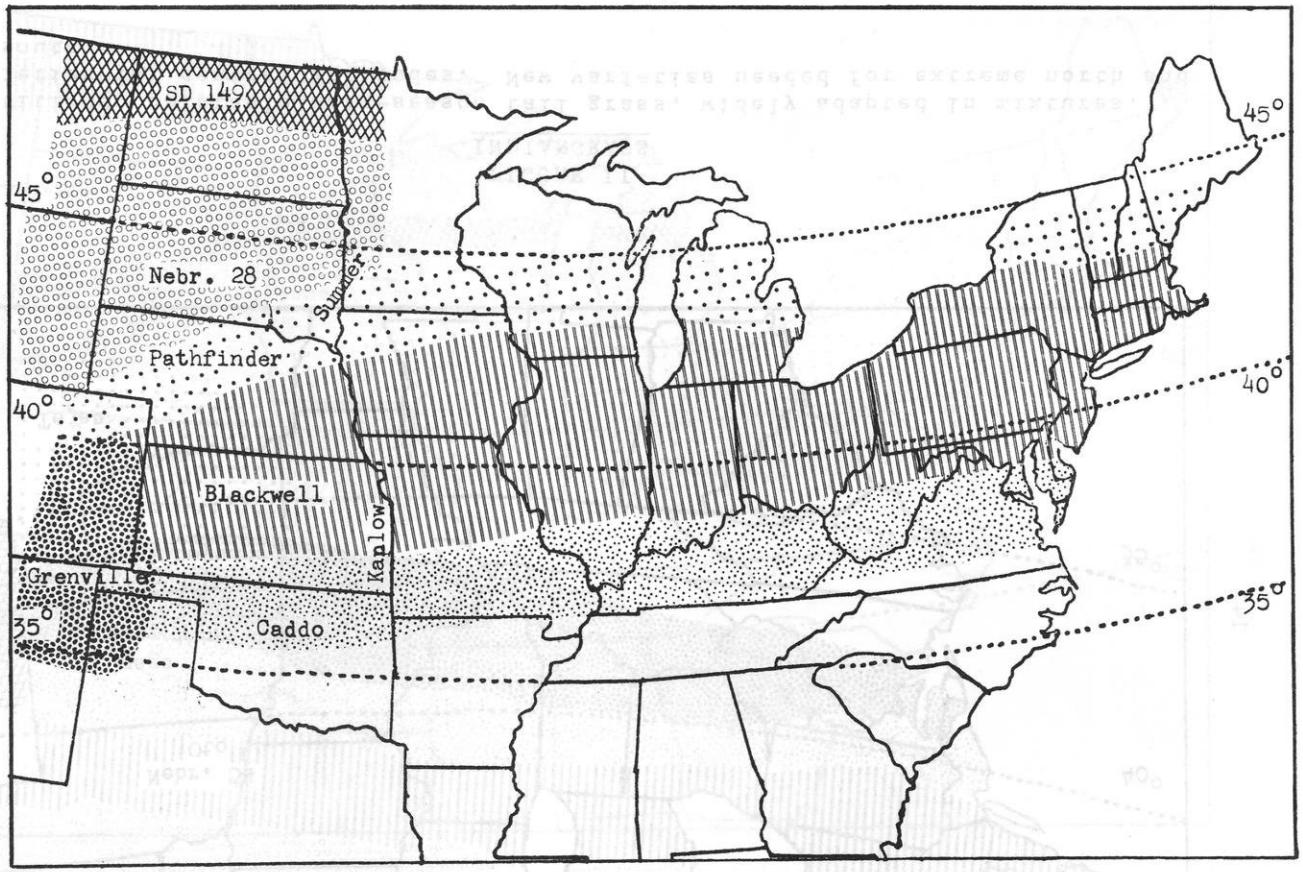


FIGURE III
SWITCHGRASS

Nutritious, palatable warm-season tall grass, widely adapted in mixtures. Nebr. 28 susceptible to rust farther east. Kanlow for wetland only. Grenville for comparatively arid conditions only. New varieties needed for south. SD 149 still experimental.

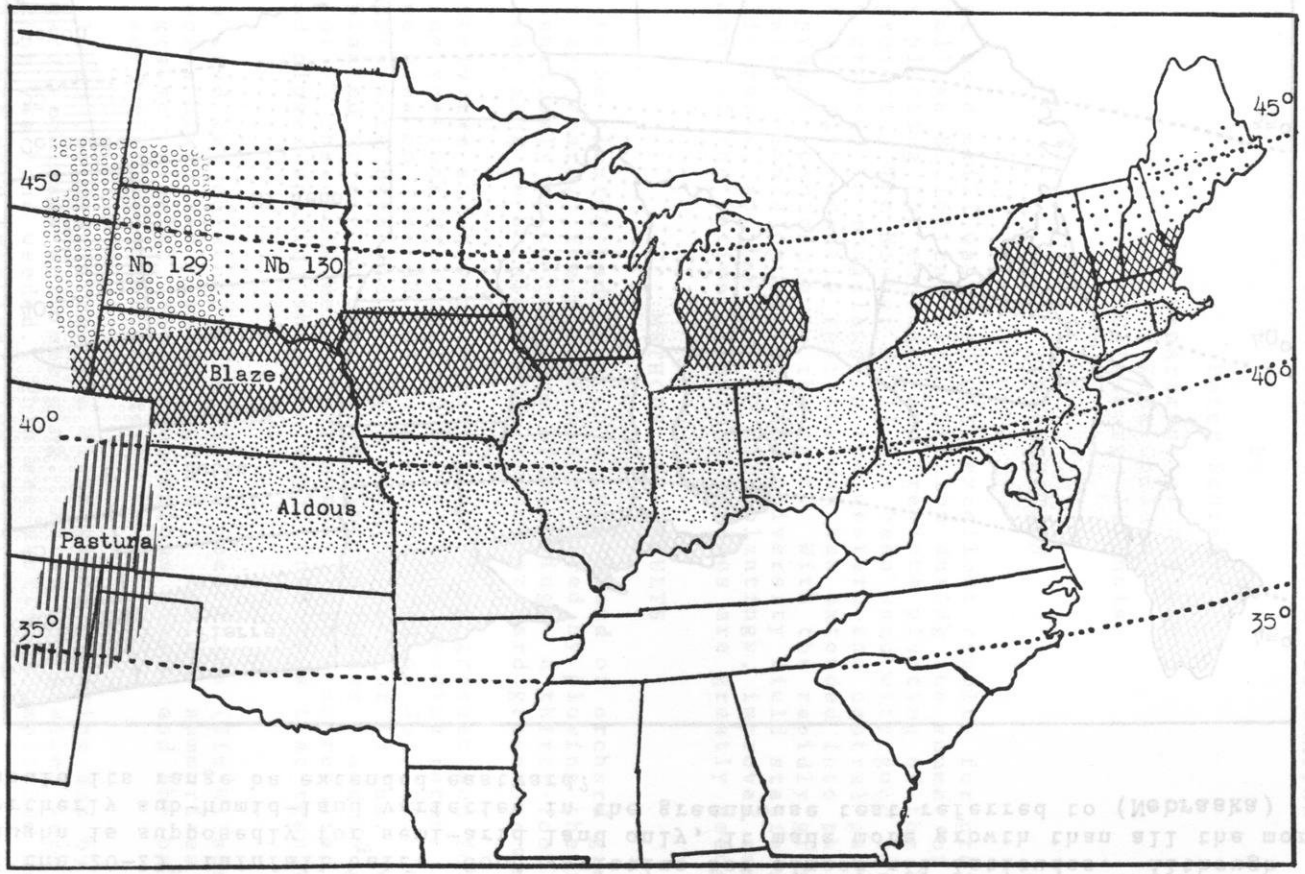


FIGURE IV
LITTLE BLUESTEM

Nutritious, palatable mid-height warm-season bunchgrass, widely adaptable in mixtures. Good varieties for central latitudes. N 129 and N 130 still experimental for mid-north. New varieties needed for south, extreme north, and possible west central.

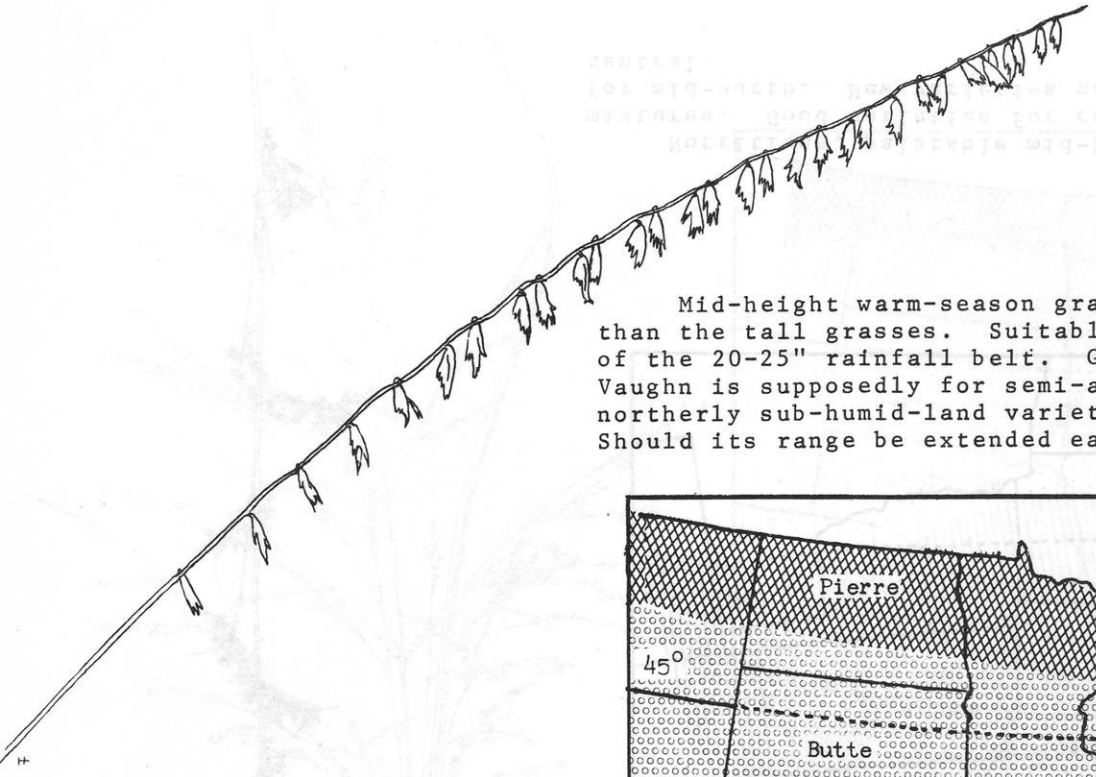
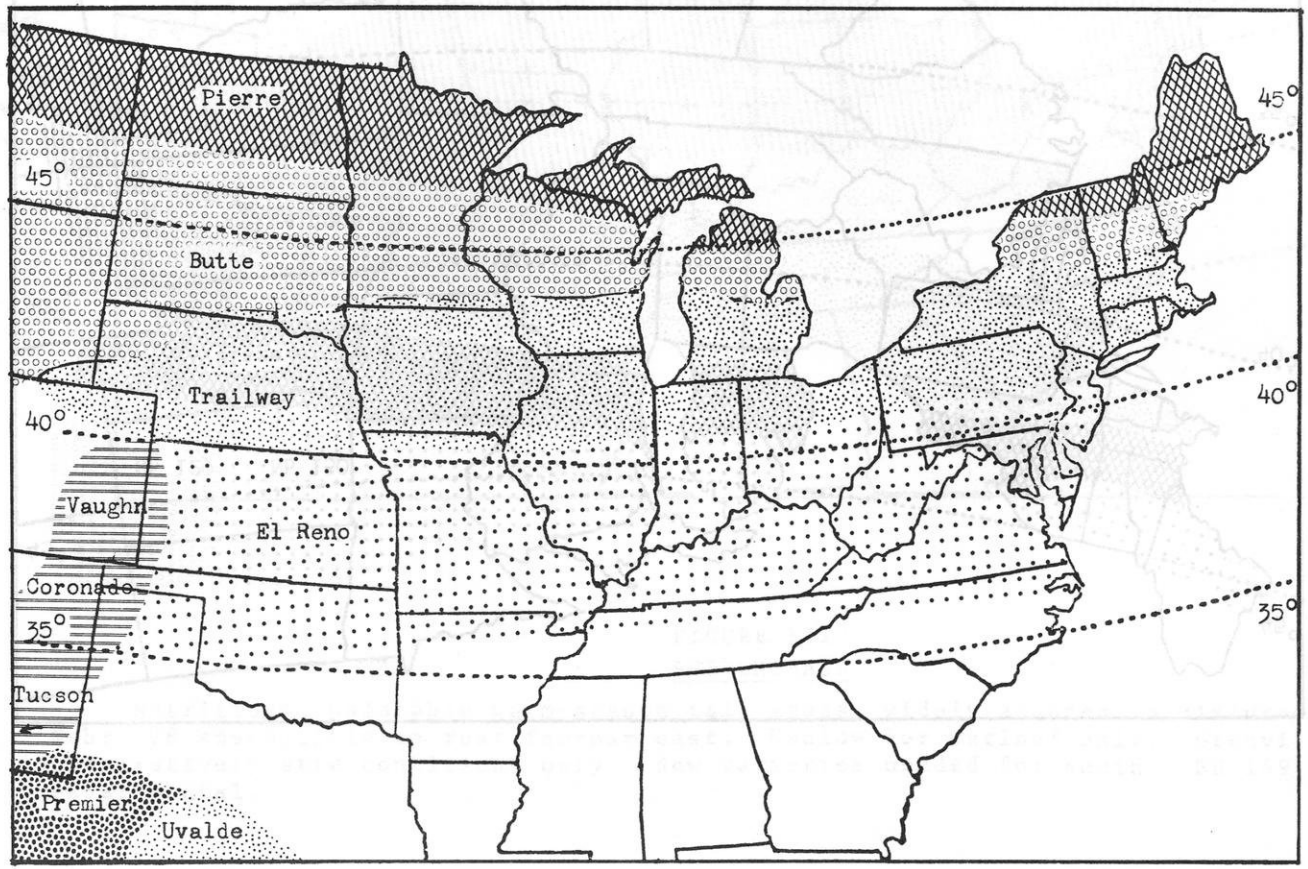


FIGURE V
SIDEOATS GRAMA

Mid-height warm-season grass, very palatable and nutritious, but lower tonnage than the tall grasses. Suitable only in mixtures for rough and rolling land, east of the 20-25" rainfall belt. Good varieties for almost all latitudes. Although Vaughn is supposedly for semi-arid land only, it made more growth than all the more northerly sub-humid-land varieties in the greenhouse test referred to (Nebraska) Should its range be extended eastward?



THE NISBET SEED DRILL IN PRAIRIE RESTORATION

By

Peter Schramm

Department of Biology
Knox College
Galesburg, Illinois

INTRODUCTION

The Nisbet seed drill was used with excellent results for prairie establishment on the Knox College Biological Field Station during the summer of 1970. The results of this planting far exceeded any previous planting of the Knox prairie restoration project. The Nisbet drill has been used with good results in the planting of native grasses on rangeland in the western and central parts of the great plains but it is only recently that its use has extended into the higher rainfall areas of the prairie peninsula to the east. With the rapidly growing interest in the use of prairie plants on college and university field stations, roadside right-of-ways, public parks, and industrial site plantings, improved and practical methods of establishment of the native grassland species are greatly needed.

METHODS AND RESULTS

The area to be planted had been in a pure stand of orchard grass, Dactylis glomerata, for ten years. The ground was prepared by plowing the fall before, and discing very shallowly up to the time of planting. A thirty-foot strip was kept mowed around the area to be planted to reduce orchard grass and weed contamination.

Approximately two acres were planted, drilling grasses and forbs at two different times. Instructions are provided for setting seeding rates. Grasses were planted on one area on June 30 and on a second area on July 15. Only the drill's large seed boxes were used and set at a seeding rate of 15 lbs. per acre. The areas to be planted were gone over three times (Figures I and II)[1] giving an actual seeding rate of 45 lbs. bulk weight per acre. This also resulted in reduced visual row effect and closer spacing than the eight inch rows that result from one pass of the drill.

The grass seed was obtained from Wilson Seed Farms (Jim Wilson), Polk, Nebraska, with four species mixed and planted together. Table 1 summarizes the species and varieties of grasses planted, their proportions mixed, and the bulk weight and lbs. of pure live seed (PLS) planted per acre.

Rains followed two days after the first grass planting and by July 6 newly germinated grass seedlings were emerging. After the grasses were well up the earlier planting was hand weeded. This was easily accomplished because the area was small and there were relatively few weeds.

Because of an unusually wet mid-summer with much rain, forbs could not be drilled into the plantings until August 10. The forb seeds had been mixed with damp vermiculite during cold conditioning and it was found that this mix had to be partially dried before it would feed through the drill. Dry vermiculite or soil could be added to accomplish the same end. Seeding rate was speeded up to about twice that of grass drilling to get more forbs into the ground in fewer passes. The drill easily cut through and planted the forbs in the newly established grass sod (see Figures III and IV)[1]. About 40 lbs. of complex forb-vermiculite mix were evenly drilled into the two-acre area. Some seeds were already germinating in the mix but were easily drilled, survived, and became established. Mid-August rains resulted in good germination of the late-planted forbs.

The total time required to drill the two acres (forbs and grasses included) was four hours.

At the time of this writing it is uncertain how well the forbs will survive and compete with the dense and well-established stand of Wilson variety prairie

[1] See Photo Section for figs. I-V.

grasses (Figure V). It is the author's present opinion that the forbs should be planted at the same time (with separate passes at the faster rate) as the grasses to assure establishment and survival in the competitive grass stand.

It is also not yet possible to determine the proportions of the four grass species that have actually been established. It is only obvious that an excellent mixed stand has emerged, almost completely free of weed competition.

The Nisbet seed drill when used in conjunction with the vigorous varieties of commercial native grass seed now available promises to greatly augment current efforts to reestablish our native grassland communities.

Table 1: Species, Variety, Proportion by Bulk Weight and Pounds Pure Live Seed Planted Per Acre.

SPECIES AND VARIETY*	PROPORTION	POUNDS BULK	LBS. PURE LIVE SEED
Andropogon gerardi Kaw Big Bluestem	2	15	8.6
Sorghastrum nutans Certified Nebraska 54 Indian Grass	2	15	10
Andropogon scoparius Native Nebraska Little Bluestem	1	7-1/2	2.7
Panicum virgatum Certified Blackwell Switchgrass	1	7-1/2	6.6

*Jim Wilson Seed Farms, Polk, Nebraska

PROPAGATION OF SPRING PRAIRIE PLANTS

By

James H. Zimmerman

University of Wisconsin Arboretum
and Institute for Environmental Studies
Madison, Wisconsin

ABSTRACT

Most prairie plantings have been confined to the most conspicuous and easily collected species - perhaps 50 out of 300 or 400 species. Whether abundant or not, the many less-well-known prairie species may prove to be important in the prairie ecosystem as well as for their own special values. Especially deficient are the forbs, and particularly those that flower in spring and in late fall.

Many of the spring prairie forbs are slow-growing, even though they may start as pioneers, probably because they tend to be cool-season ephemerals, avoiding both plant competition and summer drouth by confining most of their growth to short periods in spring and late fall. Many are facultative spring ephemerals, going dormant in June or July in dry years. Late autumn-flowering species such as asters and gentians likewise make much growth in early spring and appear to benefit from semidormancy in summer.

Greenhouse experience with Anemone patens, Geum triflorum, Phlox pilosa and Dodecatheon meadia indicates that (a) some (Geum, Anemone) do not require seed stratification; (b) organic sandy loams produce higher survival and growth rates than soils high in clay or low in organic matter; and (c) good germination and growth can be obtained in all four species. Three of them matured in the second year with two transplantings; but Dodecatheon, an obligate spring ephemeral, appears to require a minimum of 4 seasons in the absence of plant competition.

Cuttings are a feasible method of propagating Phlox and Geum, but, like meristemming, run the risk of sacrificing genetic diversity if employed exclusively. The tedious collecting of seed from the small spring and fall species can in some cases be facilitated by bagging flowering plants, in the field, or, better, in a garden row.

Control of weather extremes (especially moisture) by use of a greenhouse is important for seedling and cutting survival and development.

There is need and opportunity for prairie plant farms specializing in the propagation of a diversity of species, including various local strains, in both governmental and private enterprise. In addition to developing techniques for collecting and propagating the difficult and less well-known prairie species, the problem of when and how to introduce them into new or established prairie plantings, and in what quantity, deserves more attention.

Introduction

Planted and restored prairies generally lack both abundance and variety of spring flowering species. An example is the U.W. Arboretum's Prairie (Greene & Curtis, 1953; Cottam & Wilson, 1966). One reason is the difficulty in collecting their seeds, which ripen early and often irregularly, or in small quantity, or over a very short period, or close to the ground. Some of these, along with certain fall-flowering species presenting similar harvesting difficulties, are listed in Table 1.

A second cause of the scarcity of these species in planted prairies is the difficulty in establishing additional species once a prairie has been planted with the easily-collected ones, especially the highly competitive grasses such as Andropogon gerardi, Sorghastrum nutans, and Panicum virgatum. In order to encourage private seed farms and public agencies -- such as departments of conservation and highways and the Soil Conservation Service -- to propagate prairie species in sufficient diversity, the benefits and problems of establishing full species complexes need attention now.

Table 1: Some small spring or fall flowering midwest prairie plant species for which special restoration techniques seem desirable. (Key based on experience at Madison, Wisconsin).

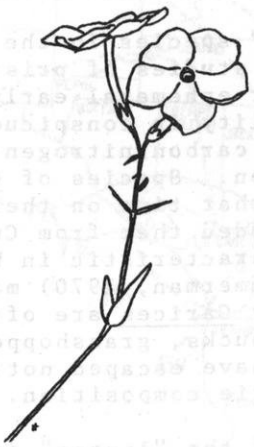
Habitat: D(dry); M(mesic); W(wet); O(often oak openings)
Flowering: S(spring); F(fall)

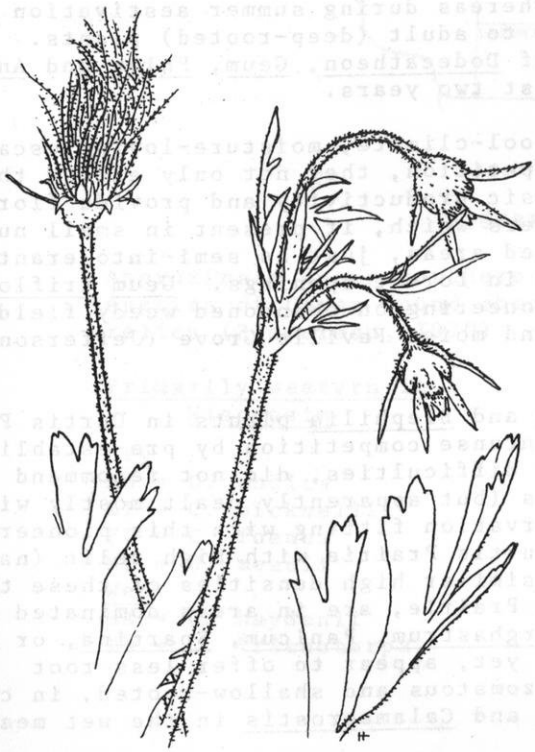
SPECIES NAME-COMMON NAME	HABITAT AND FLOWERING CODE
Anemone canadensis -- Canada anemone	SW
Anemone patens var. Wolfgangiana -- pasque flower	SDO
Asclepias lanuginosa -- Dwarf milkweed	SDO
Aster azureus -- Azure aster	FD
Aster ptarmicoides -- Stiff white aster	FD
Aster sericeus -- Silky aster	FDO
Baptisia leucophaea -- Plains wild indigo	SDM
Blephilia ciliata -- Prairie blephilia	SMW
Bulbostylis capillaris -- Sedge	FD
Camassia esculenta -- Prairie Camas	SMW
Carex abdita, bicknellii, foenea, meadii, pensylvanica, richardsonii -- sedges	SDM
Carex buxbaumii conoidea, haydenii, lanuginosa, prairea, tetanica, trichocarpa -- sedges	SWM
Castilleja coccinea -- Scarlet painted cup	SDW
Castilleja sessiliflora -- White painted cup	SD
Cirsium hillii -- Prairie thistle	SD
Comandra richardsiana -- Star toad flax	SDM
Dodecatheon meadia -- Shooting star	SDMWO
Eleocharis compressa and elliptica -- Spikerush sedges	SW
Erigeron pulchellus -- Robin's plantain	SDO
Galium boreale -- Northern bedstraw	SDWO
Galium obtusum -- Bedstraw	SW
Gentiana flavida (alba) -- Cream gentian	FDM
Gentiana puberula -- Downy gentian	FD
Gentiana quinquefolia -- Stiff gentian	FDM
Gerardia aspera, grandiflora, gattingeri and paupercula -- gerardias, foxglove	F(3D,1W,10)
Geum triflorum -- Prairie smoke	SDMW
Heuchera richardsonii -- Alum root	SDMO
Hypoxis hirsuta -- Yellow star grass	SDMW
Juncus dudleyi, greenei, interior -- rushes	S(1D,2WM)
Krigia biflora -- Prairie cynthia	SMW
Lathyrus palustris -- Marsh pea	SW
Lathyrus venosus -- Veiny pea	SM
Lilium philadelphicum var. andinum -- Wood lily	SDMW
Linum sulcatum -- Yellow flax	FD
Lithospermum canescens -- Hoary Puccoon	SDM
Lythrum alatum -- Purple loosestrife	FW
Microseris cuspidata -- Prairie dandelion	SD
Oenothera perennis -- Small evening primrose	SDW
Oxalis violacea -- Pink wood sorrel	SDO
Pedicularis canadensis - Wood betony	SDMWO
Phlox pilosa -- Hairy phlox	SDMW
Polygala senega -- Seneca snakeroot	SMW
Polytaenia nuttallii -- Prairie parsley	SDM
Prenanthes racemosa -- Rattlesnake root	FWM
Psoralea esculenta -- Pomme de prairie	SD
Ranunculus fascicularis and rhomboideus -- Early buttercups	SD(10)
Scirpus clintonii -- Sedge	SMW
Scleria triglomerata -- Sedge	SMW
Scutellaria parvula and leonardi -- small skullcaps	SDM
Senecio paupercula and plattensis -- golden ragworts	SWD
Sisyrinchium campestre -- Blue-eyed grass	SDM
Taenidia integerrima -- Yellow pimpernel	SMO
Tradescantia ohiensis -- Blue spiderwort	SDMWO

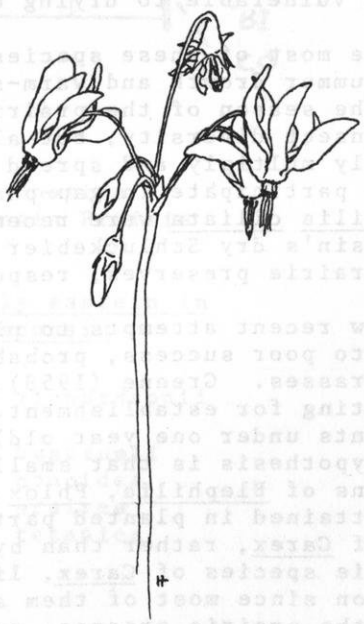
Table 1: (Continued)

SPECIES NAME-COMMON NAME	HABITAT AND FLOWERING CODE
Valeriana edulis -- Valerian	SMW
Viola pedatifida -- Larkspur violet	SDM
Wulfenia bullii -- Kittentails	SDO
Zigadenus elegans -- Death camas	SDW
Zizia aptera -- Heartleaf alexanders	SDMW
Zizia aurea -- Golden Alexanders	SMW

NOTE: Small grasses like Bouteloua hirsuta and curtipendula, Hierochloe odorata, Bromus kalmii ,and Muhlenbergia cuspidata and others belong in this list as well.







While this paper is confined to propagation, the following considerations in support of inclusion of the less well-known or less-easily handled species in prairie restorations may suggest some lines of investigation useful in introducing or establishing those species once propagated.

The spring and late fall species - mostly colorful forbs - are certainly valuable for their beauty. But they may also be important (1) in climax cycling and symbioses, and (2) as indicators of disturbance. Some, like Anemone patens, persist under light pasturing on dry limestone hills and gravelly calcareous kames and drumlins in southern Wisconsin, apparently because of lessened grass competition. Anemone owes its immunity to summer grazing to its facultative summer dormancy in dry summers as well as to the deterrant to cattle of steep hills in hot weather. For example, this Anemone is nearly as abundant on the grazed west half of the lower magnesian limestone hill whose east half is now included in the Arboretum's Raymond Road prairie preserve at Madison. But many other floriferous prairie forbs in this group, like those of the deciduous forest, appear to be very palatable, and soon all but disappeared under the onslaught of the early settlers' livestock, such as at Lake Koshkonong near Fort Atkinson, Wisconsin (Kumlien, 1876).

The true abundance and importance of these "lesser" species in the prairie ecosystem is difficult to assess, even after exhaustive studies of pristine relics like those summarized by Curtis (1949), because of their ephemeral early or late flowering, small size, and very striking yearly variability in conspicuousness, probably caused by season-to-season variations in their carbon/nitrogen ratio as well as damage by frosts, drouths, and animal consumption. Species of Carex posed a special problem because the necessity of reliance at that time on their very ephemeral mature fruits for identification totally excluded them from Curtis' students' studies; yet many Carices are abundant and characteristic in Wisconsin prairies (Figure I). Flowering and vegetative keys (Zimmerman, 1970) may eventually ease this problem somewhat. Like the spring forbs, many Carices are often eaten off over large areas, presumably by ground squirrels, woodchucks, grasshoppers, beetles and caterpillars. Thus even some abundant species may have escaped notice or been undercounted in the currently available studies of prairie composition.

From scattered observations it appears that some of the "lesser" prairie forbs are present in both very dry and very wet prairies (note some like Geum and Dodecatheon labelled "DW" in Table 1). Perhaps to them the moist soil and low evaporation rate of cool spring and fall weather is important, whereas during summer aestivation the moisture and temperature make little difference to adult (deep-rooted) plants. It was found in the present study that seedlings of Dodecatheon, Geum, Phlox and Anemone were very vulnerable to drying out in their first two years.

Since most of these species appear to be cool-climate, moisture-loving escapers of both summer drouth and warm-season grass competition, they not only extend the ends of the season of the prairie's photosynthesic productivity and provide florophilous insect diversity, but also may be pioneers which, if present in small numbers, can quickly multiply and spread to fill disturbed areas, just as semi-intolerant trees may participate in gap-phase reproduction in forest openings. Geum triflorum and Blephilia ciliata were recently observed pioneering on abandoned weedy fields in Wisconsin's dry Schluckebier (Sauk County) and moist Faville Grove (Jefferson County) prairie preserves, respectively.

A few recent attempts to plant mature Geum and Blephilia plants in Curtis Prairie have led to poor success, probably because of intense competition by pre-established prairie grasses. Greene (1958), noting similar difficulties, did not recommend transplanting for establishment of prairie forbs (but apparently dealt mostly with small plants under one year old). A final observation fitting with this pioneer-escaper hypothesis is that small parts of the Curtis Prairie with high relic (natural) populations of Blephilia, Phlox, and Geum, and similar high densities of these three species attained in planted parts of the Greene Prairie, are in areas dominated by species of Carex, rather than by Andropogon, Sorghastrum, Panicum, Spartina, or Poa. The prairie species of Carex, little studied as yet, appear to offer less root competition since most of them are sparsely rhizomatous and shallow-rooted, in contrast to the prairie grasses, and Carex stricta and Calamagrostis in the wet meadow.

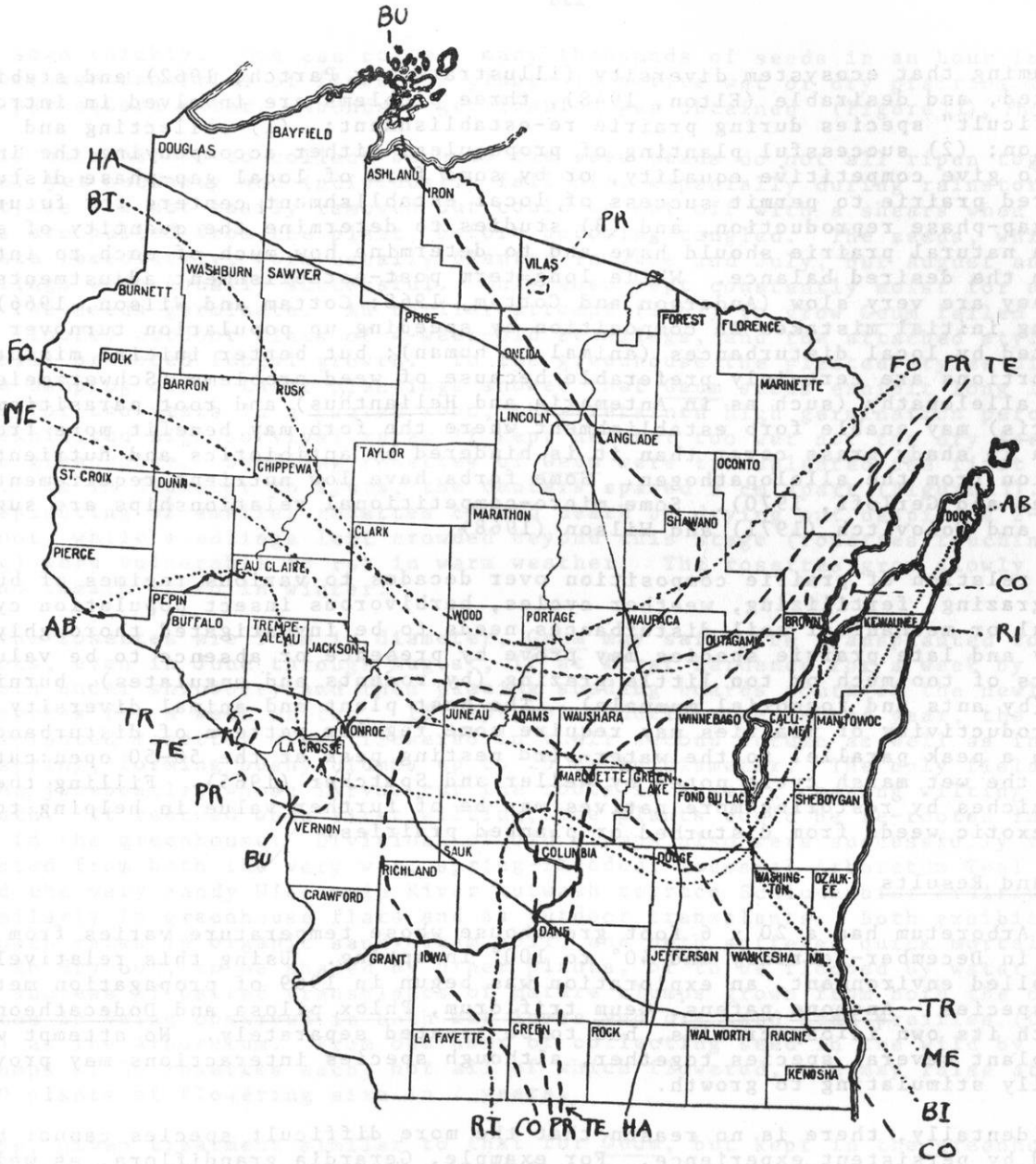


FIGURE I

Approximate known northern limits of eleven native species of Carex found abundantly in Wisconsin Prairie relics (Zimmerman, 1970)

Primarily western in Wisconsin

Dry
AB = C. abdita
BI = C. bicknellii
FO = C. foenea
ME = C. meadii
Wet
HA = C. haydenii
TR = C. trichocarpa

Primarily eastern in Wisconsin

Dry
RI = C. richardsonii
Wet
BU = C. buxbaumii
CO = C. conoidea
PR = C. prairea
TE = C. tetanica

Assuming that ecosystem diversity (illustrated by Partch, 1962) and stability are related, and desirable (Elton, 1948), three problems are involved in introducing the "difficult" species during prairie re-establishment: (1) collecting and propagation; (2) successful planting of propagules, either accompanying the initial seeding to give competitive equality, or by some form of local gap-phase disturbance of restored prairie to permit success of local establishment centers for future natural gap-phase reproduction, and (3) studies to determine the quantity of each species a natural prairie should have and to determine how much of each to introduce to attain the desired balance. While long-term post-establishment adjustments may occur, they are very slow (Anderson and Cottam, 1968; Cottam and Wilson, 1966). Correcting initial mistakes in composition by speeding up population turnover might be promoted by local disturbances (animal or human); but better initial mixtures and proportions are certainly preferable because of weed problems (Schwarzmeier, 1970). Apparent allelopathy (such as in Antemaria and Helianthus) and root parasitism (in Pedicularis) may enable forb establishment where the forb may benefit more from reduction in shady grass cover than it is hindered by antibiotics and nutrient competition from the allelopathogen. Some forbs have low nutrient requirements (Wuenscher and Gerloff, 1970). Some micro-competitional relationships are suggested by Litau and Wolovitch (1971) and Wilson (1968).

The relation of prairie composition over decades to various regimes of burning, mowing, grazing, fertilizing, weather cycles, herbivorous insect population cycles, and animal or mechanical soil disturbances needs to be investigated thoroughly. The early and late prairie species may prove by presence or absence to be valuable indicators of too much or too little grazing (by rodents and ungulates), burning, or digging (by ants and fossorial mammals). The best plant and animal diversity and animal productivity of prairies may require some regular pattern of disturbance and reach a peak parallel to the water-bird nesting peak at the 50-50 open:cattail stage in the wet marsh cycle noted by Weller and Spatcher (1965). Filling the pioneer niches by restoring more natives may be of further value in helping to exclude exotic weeds from disturbed or planted prairies.

Methods and Results

The Arboretum has a 20 x 6 foot greenhouse whose temperature varies from 20° to 60° F in December-February and 40° to 100° in spring. Using this relatively poorly controlled environment, an exploration was begun in 1969 of propagation methods of four species - Anemone patens, Geum triflorum, Phlox pilosa and Dodecatheon meadia. Each, with its own idiosyncrasies, had to be treated separately. No attempt was made to plant several species together, although species interactions may prove to be mutually stimulating to growth.

Incidentally, there is no reason that the more difficult species cannot be conquered by persistent experience. For example, Gerardia grandiflora, as well as Pedicularis and Castilleja, can be tried in either greenhouse or field by applying knowledge of the parasitic habits of Scrophulariaceous plants (Malcolm, 1962; Piehl, 1965). Rhizobium inoculation of the proper type may spell success for Lespedeza leptostachya where we had failed to raise seedlings beyond 4" in height (Burton, 1970). Knowledge of fungal associates may permit propagation and establishment of prairie orchids such as Cypripedium candidum, Habenaria leucophaea, and Spiranthes cernuua (see Stoutamire, 1964). Where seed set fails in Asclepias, transplanting either clones or insects to favor cross-pollination, as well as vegetative propagation, offer hope. However, while cuttings and meristemming techniques offer an attractive convenience for many species, asexual propagation needs to be tempered with a diversity of source material whenever possible to prevent monogenetic stands in planted prairies.

Dodecatheon is easily collected, since many of the tiny seeds remain in the erect ripe capsules throughout late summer. Dormancy is broken by refrigeration (Threlfall, 1970), by dry-cold overwintering of seeds, or by planting in moistened soil placed outdoors in fall or winter. But its main problem is its unusually short photosynthetic season (about May 1 - June 15), resulting in a 9-year maturation period for the tiny seeds sowed in situ under moderate competition in restored, occasionally burned, area of moist sandy loam in the Greene Prairie (Greene, 1958). Seedlings observed in flats kept either in the greenhouse or outdoors appear to grow equally slowly, sending up only 1-3 leaves up to 1 cm long in the second year. Flowering is anticipated in the 4th year in the present greenhouse transplants. Overwinter mortality in the small rhizomes may be high for several years under all conditions, but seed is abundant

and can be sown thickly. One can collect many thousands of seeds in an hour in the wild, because densities of flowering plants in native wet or dry prairies may reach 1-50 per square meter. Abundant germination was obtained (Figure II), Photo Section.

Geum is much harder to collect because the seed heads do not all ripen together during June, yet suddenly and individually fall off, especially during rainstorms. The long styles are not easily removed but could be cut off with a shears when the seed masses are pulled from the plant, before becoming tangled. The seeds, which can germinate immediately, were usually planted in June and July, but August and March seedlings were equally successful. Only when kept constantly moist for several weeks will the seeds germinate. An earlier attempt (1967) to grow Geum failed when a downpour flooded outdoor flats of 4-week-old seedlings, and the attached styles (left in soil) promoted fungal growth. In the greenhouse the planted styles did not promote damping off. Later plantings showed that Geum seeds exhibit long life; when stored for two years in a heated room, they retained high germination percentages. Seedlings exhibited high survival rates if kept neither too wet nor too dry for a year in the greenhouse. Seedling rosettes of Geum were transplanted the first time when 1/2 - 2 cm in diameter to flats, the centers spaced 5 cm apart (Figure II). Too-early transplanting of smaller rosettes caused death by drying out despite a 2-5 cm vertical root, while seedlings left crowded beyond this stage (rosettes touching or overlapping) were vulnerable to rot in warm weather. The rosettes grow slowly but steadily and remain green in winter.

When the rosettes are 5 cm in diameter, Geum may safely be transplanted to outdoor plots, even in June through August, if at first hardened for a week by placing flats under shrubbery and then placing shading boards south of the newly-planted rosettes for a week or two. If kept moist during the second year, the twice-transplanted rosettes often flowered in their second autumn as well as in the following spring, forming bushy clumps up to 25 cm in diameter. The only field pest was the junebeetle, whose larvae cut the roots in summer, causing wilting and gradual death. If rescued when first wilting, the plants could be re-rooted in moist soil in the greenhouse. Divisions of old clumps also were successfully rooted. Seed collected from both the very wet, spring-flooded, loessial Arboretum Teal Pond Prairie and the very sandy Wisconsin River outwash terrace Schluckabier Prairie, behaved similarly in greenhouse flats and as outdoor transplants. Both exhibited similar growth rates in organic sandy loam soil, and both suffered quick mortality if allowed to dry out, to be shaded by other plants, or to be flooded by water. The future success of paired transplants of mature clumps grown from both the dry and wet sites is being observed in both wet loess and dry sand loam prairies (Curtis and Greene) at the Arboretum. From one hour of collecting seed in the wild by hand from 30 clumps of 30 rosettes each, not all of which flowered, one may raise at least 5,000 plants of flowering size in 2 years.

Anemone, given treatment similar to that for Geum, but kept in the greenhouse the second year to prevent over-wetting by rains, proved to be just as easy, and some transplants produced flower buds in the flats by the end of the second summer. These were successfully transplanted in October, growing all of the following summer in calcareous gravelly - sandy organic loam on a knoll under an oak opening (of Quercus velutina and macrocarpa) in company with a single native plant of Anemone patens (Green Prairie). The competition by Poa pratensis and compressa, Bouteloua curtipendula, Andropogon scoparius and Carex pensylvanica was lessened here by the trees' partial shade. The geum-like seeds were collected on ripening (when easily separated from the receptacle) in late May and planted immediately. Although they grew in both clay and sand soils, the best growth, as for Geum, was in a limey sandy loam high in organic matter (which happened to be derived from oak litter). Like Dodecatheon and probably others, Anemone seems to require a good supply of lime, and thrives well in nature where thin loess covers ridges of Oneota dolomite and kames of Niagra limestone rubble.

Observations of mature native prairie plants suggest that this Anemone is a facultative aestivator; it may remain green throughout a wet summer, but when, in July, the spring leaves dry up in dry, hot weather, a second set of leaves may be sent up in September. Given water continuously during the summer, the Anemone seedlings in the greenhouse continued to grow steadily from June through September(fig. IV but were very thin-leaved, delicate, succulent, and prone to quick wilting when dry. The seedlings grew much faster if kept moist than if the soil was allowed to dry out somewhat each day; they were not tested under summer drouth conditions, nor under direct full-sunlight until September. Some drying is probably desirable to

harden the plants and promote root growth. The paucity of seedlings in native prairie may be related to the infrequency of wet summers, which may be necessary for establishment of the characteristically deep root system that makes transplanting of mature plants generally unsuccessful even when dormant (winter or summer).

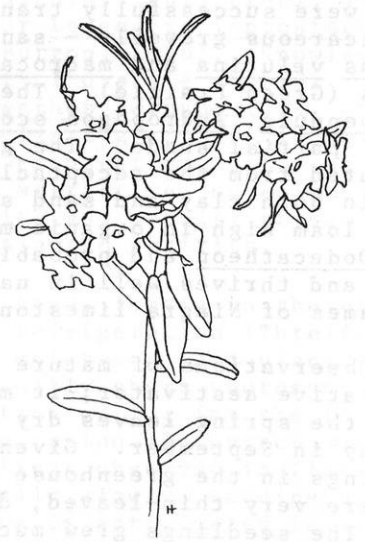
Phlox was easy to grow, flowering in the second season, but germination percentage was very low (as in Greene and Curtis, 1950), even with the seed stratification methods used (cold moist storage, or outdoor wintering in soil). The greater difficulty with Phlox is the requirement of special collection techniques. Since the few large black seeds ripen and drop at different times during June and July, bags that admitted light and air were placed over wild-growing plants that were finishing flowering in late May, and loosely tied around the stem. Under the weight of the bag, the plant bent down, leaving the partly tied opening upward, so that the seeds fell into the base of the bag, easily collected in July or August. Used nylon stockings proved less durable than cheesecloth or mosquito netting. Seeds collected per bag (1-3 stems) averaged 10; obtaining 500 seeds involved about 5 man-hours of bagging, harvesting, and sifting from chaff.

Bags of finer material may prove successful in keeping seminophagous insects out at both the late flowering and fruiting stages in species readily attacked, such as in Baptisia, Gentiana, Castilleja and Lilium. Bags now being tried out on other species show that a very difficult one, Lithospermum canescens, will yield about 15 seeds per plant (several stems) if marked when in flower and bagged when the first seeds begin to fall. 500 seeds of unknown germinability resulted from 4 man-hours of bagging, collecting and extracting from chaff (the upper stems were clipped and collected in the bags and dried). On other species which do not drop seeds readily, the plant stems can be harvested when dormant. Two mature plants of Psoralea esculenta, for example, yielded 100 seeds in July. In both Lithospermum and Psoralea, fertilized flowers were less than 50%. Although having 4 ovules against Psoralea's one, Lithospermum rarely produced over one seed per flower. The large hard white seeds of three sand barren species, Lupinus perennis, Lithospermum croceum, and Lithospermum incisum, are more abundantly produced and can be easily collected from the bare sandy ground after they fall, before the rains bury them.

Growing Phlox and Lithospermum in a nursery row might lead to labor-saving seed collecting procedures. Rooting of cuttings of Phlox was found to be possible, and especially desirable because the weak and brittle-based Phlox stems often broke when being bagged or collected, or when seedlings were transplanted. These stems could be salvaged by re-rooting them in moist soil. In certain other prairie species, such as Lithospermum and Baptisia, however, cuttings will probably not take root.

The only greenhouse problems were aphids on all 4 species -- controlled by placing the flats outdoors in lower humidity -- and fungal growths when the soil was too waterlogged and temperatures and humidity both were too high. Moisture and heat were controlled by using organic sandy loams and erecting adjustable bamboo shades over the glass in March through August.

The high survival of seedlings with weeding, thinning when crowded, and greenhouse control of moisture and heat enhances speed of propagation. This efficiency is desirable where seeds are scarce or difficult to collect. However, the lessening of natural selection for ability to compete at the critical seedling stage, and sometimes selection for uniform behavior in greenhouse and garden, may work against long term survival and genetic diversity in planted prairies if carried out too often. Use of a variety of sources and encouragement of natural seeding would be desirable in the long run.



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STUDIES ON THE GERMINATION OF DODECATHEON MEADIA

By

Anna M. Threlfall
Student, Madison Memorial High School-1968

ABSTRACT

Using moistened paper tissue in petri dishes, shooting star seeds were found to exhibit a direct relation between the length of stratification and the percentage of seeds germinating. The rise in the curve was the sharpest in the first week, then slowed down during the second week, and thereafter almost leveled off. The average germinating percentage for two weeks of stratification was 83%, the highest figure being 91%, both figures more than double those of Greene and Curtis; hence shooting star seeds can have a good germinating capacity and require only a few days of stratification.

Introduction

The University of Wisconsin has established with good results two prairie communities in the Arboretum by direct seeding. While establishing the Arboretum prairies, Greene and Curtis (1950) tested the germination behavior of many prairie plants, including the shooting star (Dodecatheon meadia). They confirmed earlier findings that the shooting star seeds required a period of stratification to induce germination. Stratification, according to Barton and Crocker (1953), is any moist, low-temperature pretreatment used to induce germination which would not otherwise occur. The seeds must be imbibed and the temperature is usually between 1° and 10° C. Green and Curtis ran three trials over a period of three years on the germination of shooting star seeds. They stratified the seeds for two months in soil flats for each experiment. An average of 39% of the seeds germinated furing the three years with 44% being the highest figure. Without stratification none germinated.

With the increasing interest throughout the country in establishing prairie communities, a knowledge of the germination behavior of prairie plants is useful in determining the seeding rate and planting season. Because the shooting star, which is a prairie plant in the Madison area, has not produced good stands through direct seeding, and because Greene and Curtis' germination results were rather low, I chose to study it in more detail. The main purpose was to find out if Greene and Curtis' two months of stratification was the threshold for any appreciable amount of germination, or if there was a direct gradient relating the length of stratification to the germination percentages.

Procesures and Results

The seeds were collected when ripe from a xeric prairie on a limestone hill in Middleton in 1966 and 1967, both in Dane County, Wisconsin. The seeds were stored at room temperature (about 70° F and 21° C) until used. Because of Greene and Curtis' low germination results in the soil, the seeds in this experiment were sown in moistened kleenex in petri dishes. 200 seeds were counted into each petri dish for the first year's experiments (1967), but because of the difficulty in counting so many seeds, only 100 were used the following year (1968). These were pl placed in a home refrigerator for varying periods. During the second year's experiments the petri dishes were kept in plastic bags to prevent drying. The temperature fluctuated between 5° and 10°C as determined with a thermometer kept in the refrigerator. After stratification the seeds were taken into room temperature to germinate.

1966 Middleton seeds were stratified from 1-12 weeks with one petri dish being removed weekly from the refrigerator. The results were erratic but showed no definite threshold (Figure I). However, two weeks of stratification gave 91% germination results, the best of the twelve weeks tested, and even one week gave slightly better results than Greene and Curtis obtained. One petri dish was left in stratification until germination and after six months 95% of the seeds germinated. The next year, 1968, seeds collected from both Middleton and Sauk City and gave only 76% and 70% germination results respectively after two weeks stratification, suggesting that the 1967 seeds needed a longer cold treatment. Three weeks of treatment increased Sauk City seed germination to 85%, after which the gradient leveled off. The difference between the erratic behavior of 1966 seed in 1967 and the levelling off of the 196

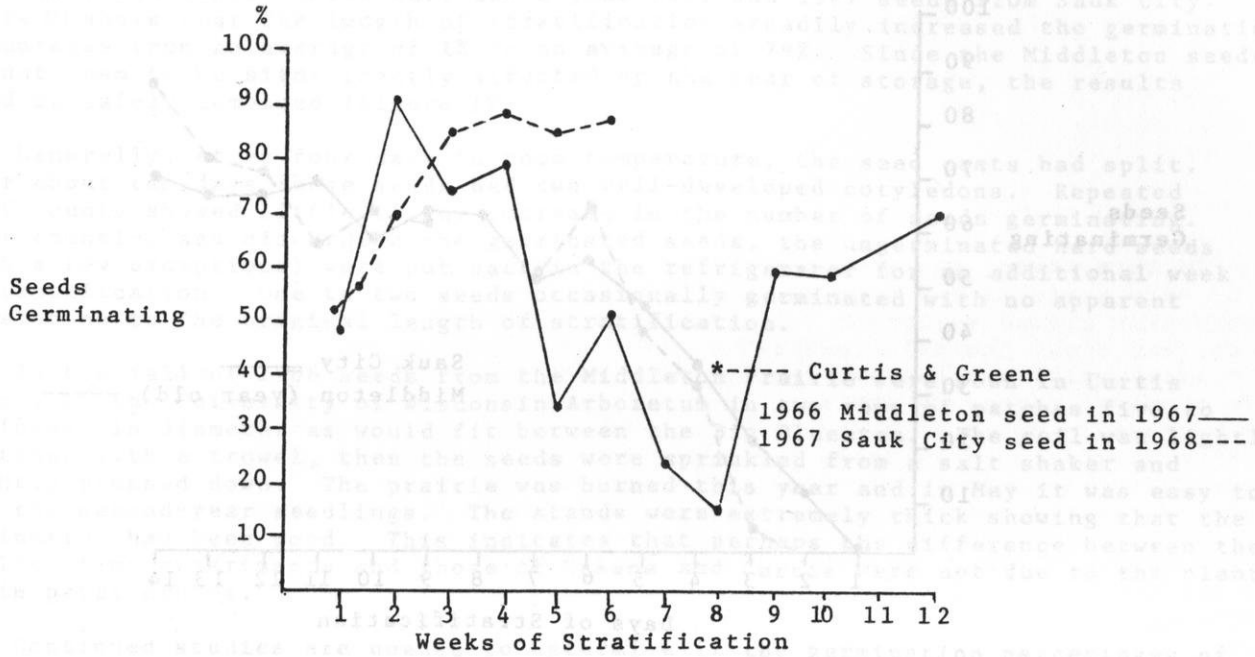

FIGURE I: 1-12 Weeks of Stratification

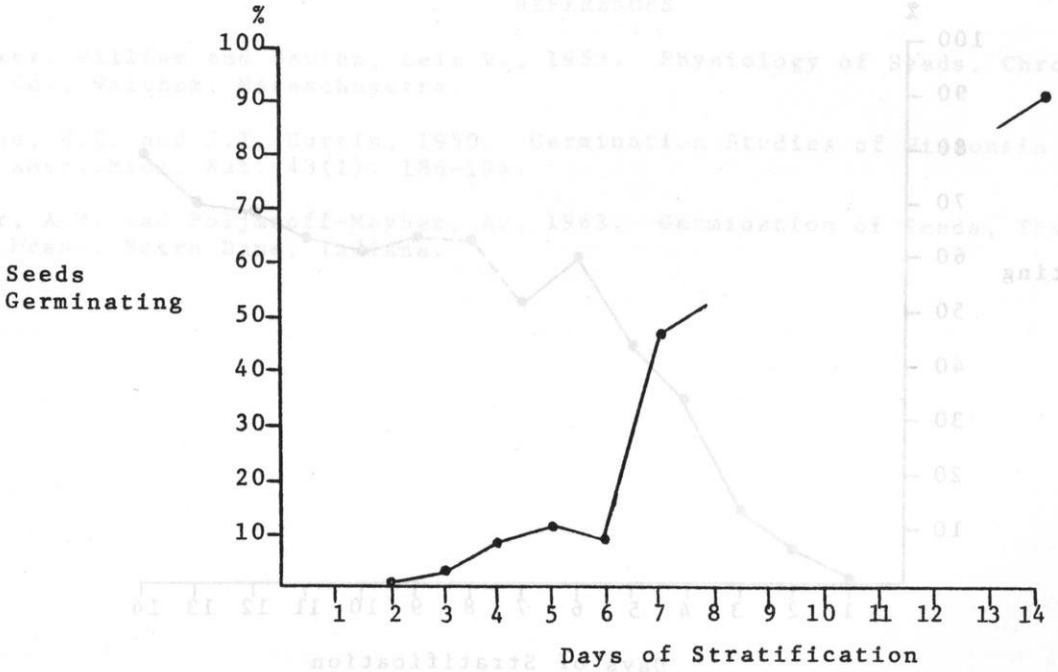

FIGURE II: 1-6 Days of Stratification in 1967

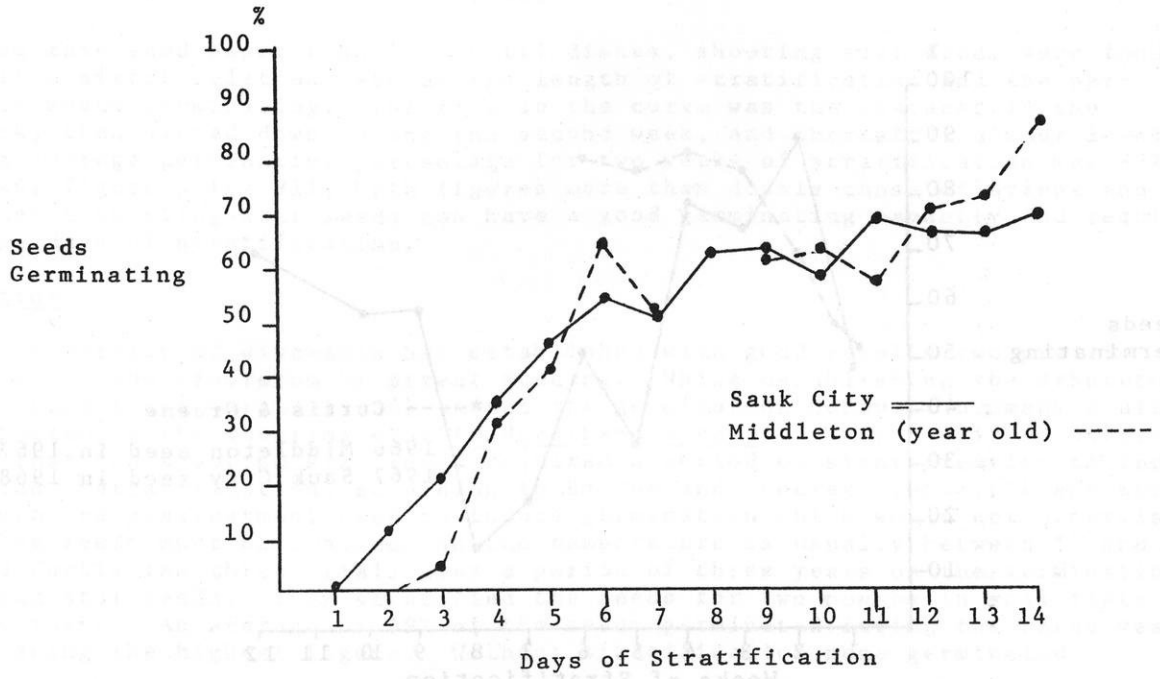

FIGURE III 1-14 Days of Stratification in 1968

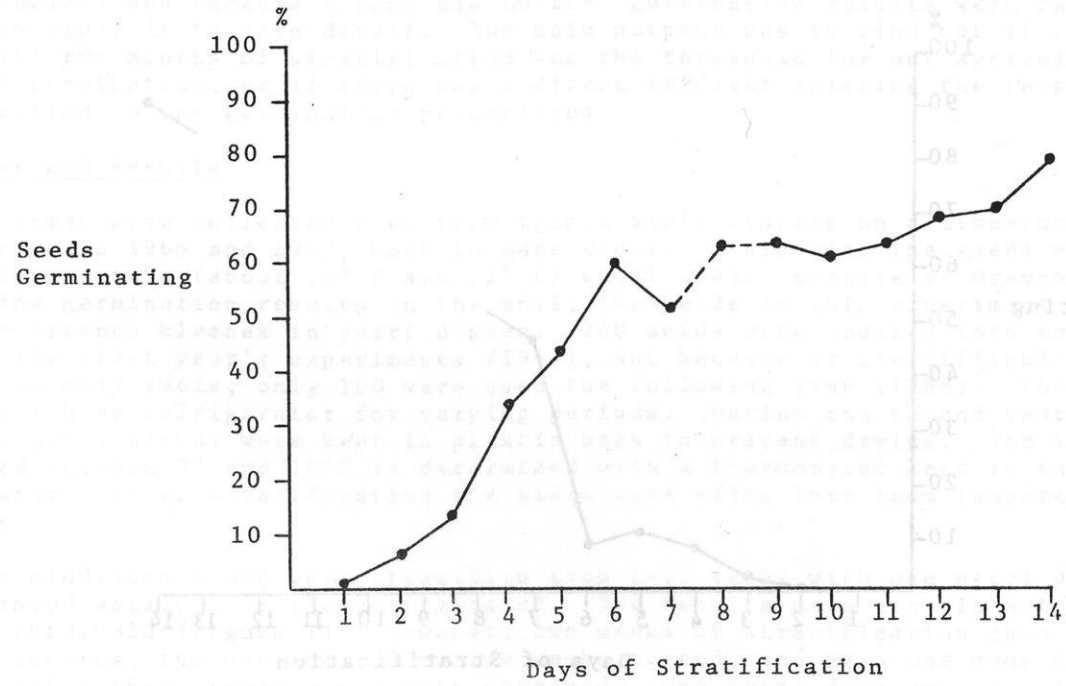

FIGURE IV Averaged Results of 1-14 Days Stratification

seed in 1968 was probably due to some drying out of the former (Figure I).

In order to determine the minimum length of stratification, Middleton 1966 seeds were stratified from 1-6 days in 1967. Since there was an indication of a gradient (Figure II) pointing upward if one includes the percentages for 7 and 14 days (Figure I), this trial was repeated the following year for 1-14 days, using 1966 Middleton seeds, which were now a year old, and 1967 seeds from Sauk City. Figure III shows that the length of stratification steadily increased the germination percentages from an average of 1% to an average of 79%. Since the Middleton seeds did not seem to be significantly affected by the year of storage, the results could be safely combined (Figure IV).

Generally, after four days in room temperature, the seed coats had split. After about ten days these seeds had two well-developed cotyledons. Repeated later counts showed little if any increase in the number of seeds germinating. After counting and discarding the germinated seeds, the ungerminated hard seeds (with a few exceptions) were put back in the refrigerator for an additional week of stratification. One to two seeds occasionally germinated with no apparent correlation to the original length of stratification.

In the fall of 1966 seeds from the Middleton Prairie were sown in Curtis Prairie in the University of Wisconsin Arboretum in two rows of patches five to six inches in diameter as would fit between the Big Bluestem. The soil was lightly scratched with a trowel, then the seeds were sprinkled from a salt shaker and slightly pressed down. The prairie was burned this year and in May it was easy to find the second-year seedlings. The stands were extremely thick showing that the germination had been good. This indicates that perhaps the difference between the results of my experiments and those of Greene and Curtis were not due to the planting in petri dishes.

Continued studies are needed to determine if the germination percentages of shooting star seeds from the same location vary appreciably from year to year, and to determine the effect of fluctuating temperatures, as occur in nature.

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INTRODUCTION, DISPERSAL, AND POPULATION INCREASE OF THE FRANKLIN'S GROUND SQUIRREL, SPERMOPHILUS FRANKLINII, IN A RESTORED PRAIRIE

By

Aleeta Van Petten

And

Peter Schramm

Department of Biology, Knox College
Galesburg, Illinois

ABSTRACT

In this study, the restored prairie on the Knox College Field Station was found to be very suitable for a successful introduction of the Franklin's ground squirrel. Twenty-nine ground squirrels (four adult males, seven adult females, ten juvenile males, and eight juvenile females) were originally trapped in the wild and released into artifically dug burrows during the summer of 1969. Although these burrows may have provided temporary shelter, most of the ground squirrels moved around and dug new burrows in sites of their own choosing. The clay timber soils on the field station proved to be suitable for establishing liberation burrows. A live trapping study during the summer of 1970 indicated the following: (1) the ground squirrels dispersed widely over the available prairie plantings, but seemed to concentrate in the richer, deeper soils and more mesic prairie sites. (2) Nine animals of the original number released were captured this second summer. (3) These one-year old and adult animals successfully bred in 1970 and produced at least 34 juvenile ground squirrels. (4) Juvenile males emerge from the parental burrows before juvenile females. (5) Juvenile sex ratio was 1:1 while the number of adult males trapped was far below the number of females captured; the significance of this result was not clear. (6) Juvenile males appeared to gain weight faster than juvenile females, with weight gains slowing with increased age. (7) All emerging females showed signs of successful breeding, with approximated average litter size of 6.8. The introduction can be characterized as relatively successful, with wide dispersal into the available habitat, further adjustments to the more favorable sites, and significant reproduction and population increase in an unfilled environment.

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Introduction

The Franklin's Ground Squirrel, Spermophilus franklinii, is a large gray ground squirrel which inhabits tall grassy areas of the central United States, north into southern Canada. This tall grass habitat preference suggests that it is a climax species of the tall grass prairie. While not abundant over large areas, it may be found locally in widely scattered colonies, but over much of the midwest it is absent because of destruction of suitable habitat by mowing, grazing, and cultivation.

In the light of its increasing rarity and its assumed preference for prairie habitat, it seemed highly desirable to introduce and attempt to establish this ground squirrel in the prairie being restored on the Knox College Biological Field Station located in eastern Knox County in west-central Illinois. If successful, such an introduction would augment the numbers of this species in this area and provide a protected population that could be studied on a long-term basis.

Materials and Methods

Hav-A-Hart traps were used to live-trap the ground squirrels. These were modified with a spring on the trigger and a stiff "stop" wire under one side of the trip pan to eliminate capture of smaller rodents and birds. Trap sizes one and two were used with no apparent differences in capture results.

The trapped squirrels were examined and handled in a one-half inch mesh sock-shaped fish net. They were weighed, toe-clipped for identification, reproductive condition and pelage checked and location noted. All data were recorded on IBM

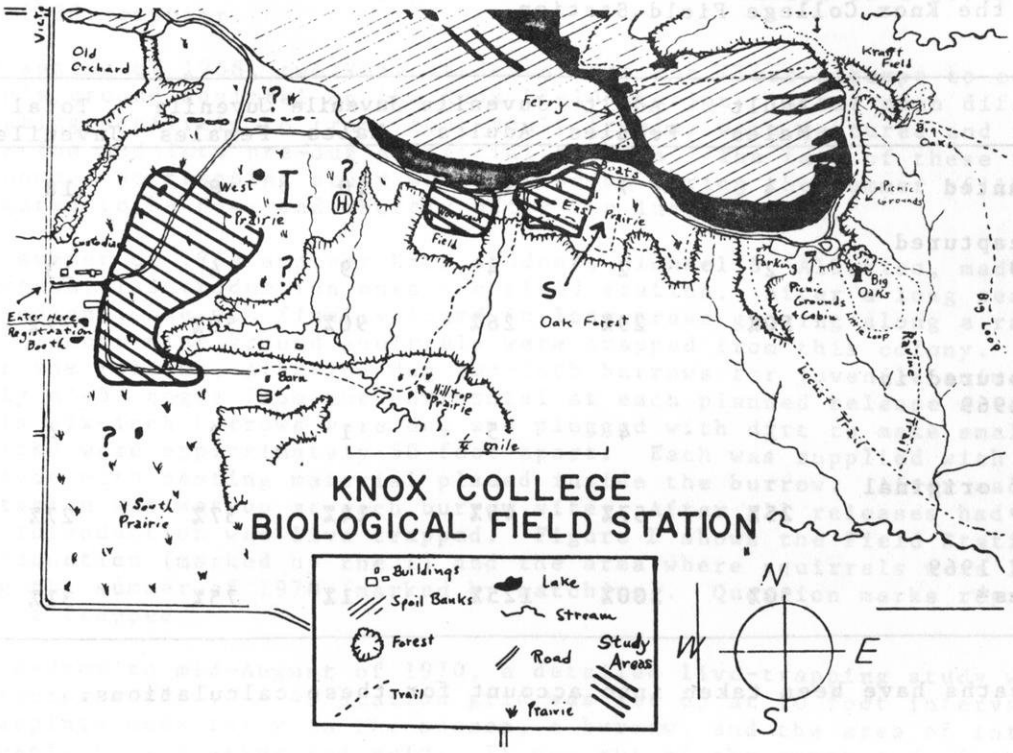

FIGURE I

Map of Knox College Field Station showing area of introduction (I) near the future headquarters building (H), and area where ground squirrels were later captured during summer of 1970 (marked by hatching). Question marks indicate areas not extensively trapped.

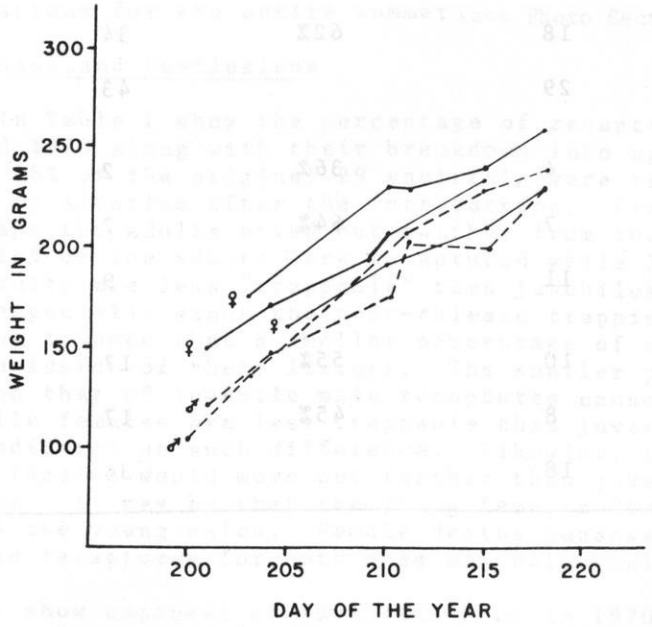

FIGURE III

Growth curves for selected individual juvenile Franklin's ground squirrels.

Table 1: Comparison of Recaptures, 1969-1960, of The Franklin's Ground Squirrel on the Knox College Field Station.

	Adult Males	Adult Females	Juvenile Adults	Juvenile Males	Juvenile Females	Total Juveniles	Total Squirrels
Squirrels planted	4	7	11	10	8	18	29
Squirrels recaptured in 1969	2	2	4	9	4	13	17
Percentage	50%	29%	26%	90%	50%	72%	59%
Squirrels captured in 1970 from 1969 plant	1	4	5	1	3	4	9
Percentage of original plant*	25%	57%	45%	14%	37%	27%	35%
Percentage of 1969 recaptures*	50%	200%	125%	1%	75%	31%	53%

*All known deaths have been taken into account for these calculations.

Table 2: Comparison of Age and Sex Composition of the 1969 and 1970 Populations of Franklin's Ground Squirrel on The Knox College Field Station.

	1969		1970	
	Number	Percentage	Number	Percentage
Adults	11	38%	9	21%
Juveniles	18	62%	34	79%
Total squirrels	29		43	
Adult males	4	36%	2	22%
Adult females	7	64%	7	78%
Total adults	11		9	
Juvenile males	10	55%	17	50%
Juvenile females	8	45%	17	50%
Total juveniles	18		34	

mark-sense cards which were later punched and could be handled on a sorting machine and the IBM 1130 computer.

In the spring of 1968, two Knox students made the first attempt to establish the Franklin's ground squirrel on the Knox Field Station. After much difficulty in even locating squirrels to trap, four adult females were captured and introduced onto the station and into pre-dug artificial burrows. The fate of these four females remains unknown. No trapping study was carried on during the summer of 1968. The burrows appeared to be deserted shortly after the introduction.

In the summer of 1969 another Knox student, Michael S. Alberico, made a large and very successful introduction onto the field station. After a long search for a large local colony, one was finally found in long grass growing along a railroad embankment. Twenty-nine ground squirrels were trapped from this colony. In preparation for the release, Alberico dug two-inch burrows for juvenile animals at approximately a 45° angle from the horizontal at each planned release site. For adult animals six-inch burrows were dug and plugged with dirt to make smaller entrances. Sites were approximately 50 feet apart. Each was supplied with corn and sunflower seeds with nesting material placed inside the burrow. After each release, a feeding station was set up at each burrow site. After all releases had been made, the area of introduction was live trapped. Figure I shows the Field Station, the area of introduction (marked by the I) and the area where squirrels were later captured during the summer of 1970 (marked by hatching). Question marks represent areas which were not trapped.

From mid-June to mid-August of 1970, a detailed live-trapping study was carried out by the senior author. A 49 station grid was set up at 70 foot intervals. Sightings and trappings made early in the season, a burrow, and the area of introduction provided a basis for locating the grid. It was put at the north end of the introduction area. Spot traps were also set out at the same time to locate squirrels outside the grid. No squirrels were caught regularly on the grid. After two weeks of getting better results from spot traps outside the grid, the grid traps were moved.

All of the field station was not trapped. It was too large an area to trap intensively enough for significant numbers of captures of various individuals. To solve this problem, several "areas of activity" were located and seven traps were placed at approximately 50 feet apart. These areas were chosen on the basis of sightings and spot trappings. This resulted in increased adult captures, and young of the year also began to be taken. Figure II shows capture sites, individual sightings, and burrow locations for the entire summer (see Photo Section.).

Observations, Discussion and Conclusions

The data given in Table 1 show the percentage of recapture of the original 29 squirrels in 1969 and 1970 along with their breakdown into age and sex. As shown in the table, 17, or 58% of the original 29 squirrels were recaptured in 1969 in the week of trapping by Alberico after the introduction. From these figures it may be assumed that perhaps the adults moved out farther from the release area than did the juveniles; only 26% of the adults were recaptured while 72% of the juveniles were. However, if adults are less "trappable" than juveniles, this could account for the difference, especially since the post-release trapping period was so short. It is also interesting to note that a smaller percentage of adult females might range farther than males in search of their litters. The smaller percentage of juvenile female recaptures than that of juvenile male recaptures cannot be explained so easily. It is not that juvenile females are less trappable than juvenile males because trapping data from 1970 indicated no such difference. Likewise, there is no reason to assume that juvenile females would move out farther than juvenile males--although this could be the case. It may be that the young females did not survive the transplant as well as the young males. Female deaths because of the transplant could be a reason why female recaptures for both ages was below male recaptures.

Table 1 does not show captures of juveniles born in 1970. The squirrels listed under juvenile headings for the 1970 captures were juveniles in 1969 and were one-year-olds in 1970. The row of percentages labeled "Percentage of original plant" represents what percent of the original plant was captured in 1970. The one labeled "Percentage of 1969 recaptures" shows what percent of 1969 recaptures were caught in 1970. Except for two extra females all the squirrels caught in 1970 had been recaptured in 1969. In both comparisons the percentage of one-year-olds being

recaptured is smaller than that of adults being recaptured. Compared to the original plant 45% of all adults were recaptured while only 27% of all juveniles were recaptured. In comparison to 1969 recaptures, 125% of all adults and 31% of all juveniles were recaptured. This may indicate higher winter mortality and perhaps greater dispersal on the part of the young before hibernation although dispersal could not have occurred normally since at least some of the juveniles had already been separated from their mothers and litter-mates. The high percentage of female recapture over male recapture among both adults and yearlings is somewhat of a mystery--especially since among 1969 juveniles males numbered greater than females. This could indicate a greater male mortality or dispersal or possibly a post-breeding season period of male inactivity. Also, it could indicate a greater trap-shyness on the part of the males. A sighting record of a male marked by a short tail that was not trapped seems to suggest that there may be males on the station that are not trappable.

Age and Sex Composition

In Table 2 the age and sex composition of the 1969 and 1970 populations were compared. Of the two years, the data from 1970 are probably the most accurate throughout, because the 1970 trapping was more intensive and lasted over a longer period of time. In 1969 the table shows that 38% were adults and 62% were juveniles, but in 1970, 21% were adults and 79% were juveniles. This may be because not all juveniles had yet emerged from their burrows during the 1969 trapping.

Comparing the number of juvenile males to juvenile females in 1969 and 1970, one can see that there has been a small change here also, although in both samples the male-female ratio is nearly 1:1. Although it is not safe to make generalizations when the numbers are so small, the smaller percent of juvenile female captures in 1969 could be because juvenile females emerge from the burrow later than juvenile males as was indicated from 1970 observations still to be discussed (Table 3). Since the trapping of the original area was not continued late into the season, all juvenile females were not yet out at the mid-summer time of trapping.

In comparing adult males to adult females the percentages also changed from 1969 to 1970. Some factor is indicated which keeps more males out of the trapping than females. The juvenile sex ratio is evenly split while there are many more adult females than adult males. Table 1 also indicates that there is something that happens after the first year to keep juvenile males from appearing in the trapping when they become one-year-old adults. This factor may be mortality, dispersal, inactivity, untrappability, or something altogether different. This reduced rate of capture of adult males remains unexplained.

Dispersal

The dispersal and spacing of the ground squirrels was of special interest in this study. Lack of captures in the original area of introduction (see I, Figure I) and subsequent captures in other parts of the field station indicated that the ground squirrels dispersed rather widely after being introduced. Many of the squirrels tended to cluster and establish on the deeper, richer soil and more mesic sites of the study area. The original area of introduction, although it had rather similar prairie vegetation, had thinner soil, was better drained and more xeric. Although comparative soil tests and vegetational analyses were not conducted, the animals seemed to choose and establish in the richer more productive sites of the restored prairie. Factors of the habitat that influence ground squirrel establishment need much more study.

Reproduction

The detailed reproductive biology of this ground squirrel is still rather poorly known. The following is a summary of reproductive data derived from this study. Two of the four females trapped during the spring of 1968 appeared to be in estrus condition on May 18 and 20, respectively. A third female appeared to be pregnant on May 20. Estrus females were taken on May 23, 1970. The females were lactating by the time trapping was begun the summer of 1970 with the first record of a lactating female dated June 30. Young were first trapped on July 19 with approximately two months elapsing between observed estrous and the emergence of the first young from the burrow.

Table 3: Juvenile Franklin's Ground Squirrel Captures, 1970.

Trap Day			Captures		New Captures	
			Male	Female	Male	Female
200	July	19	1	0	1	0
201		20	4	2	4	2
202		21	2	0	1	0
203		22	3	2	1	2
204		23	5	4	3	2
205		24	2	2	1	1
206		25	-	-	-	-
207		26	-	-	-	-
208		27	3	4	2	1
209		28	3	1	0	0
210		29	6	8	2	4
211		30	7	6	1	4
212		31	-	-	-	-
213	August	1	-	-	-	-
214		2	-	-	-	-
215		3	6	9	0	0
216		4	-	-	-	-
217		5	-	-	-	-
218		6	-	-	-	-
			10	9	1	1
			52	47	17	17

Table 4: Weight Gains of 1970 Juveniles

MALES				FEMALES			
Weight Range	Weight Gain	Days Elapsed	Grams Gained Per Day	Weight Range	Weight Gain	Days Elapsed	Grams Gained Per Day
105-240	135	18	7.5	150-235	85	14	6.1
110-175	65	8	8.1	175-260	85	15	5.7
125-130	105	14	7.5	135-210	75	11	6.8
125-220	85	14	6.1	130-180	50	7	7.1
145-240	95	14	6.8	160-230	70	13	5.4
155-240	85	14	6.1	125-170	45	10	4.5
150-235	85	10	8.5	225-280	55	8	6.9
100-155	55	10	5.5	195-230	35	8	4.4
135-220	85	10	8.5	200-230	30	8	3.7
120-230	110	17	6.5	130-170	40	7	5.7
				135-160	25	7	3.6
				145-210	55	8	6.9
7.1 GRAMS GAINED PER DAY ON THE AVERAGE				5.6 GRAMS GAINED PER DAY ON THE AVERAGE			

As has been indicated, very few adult males have been caught in this study. Their reproductive condition was judged by the external appearance and enlargement of the scrotum and testis. June 30 was the earliest capture of an adult male during 1970, and he was reproductively active. July 8 was the last capture of an active male, while July 25 was the first capture of an inactive male. On the same day a slightly active male was trapped. This leaves a period of 17 days during which no adult male captures were made and therefore for which there are no male reproductive data. The data suggest, however, that males do not become completely inactive until the last part of July.

Juvenile Emergence and Captures, 1970

In the summer of 1970, 34 juvenile Franklin's ground squirrels were trapped. Table 3 summarizes the capture data for these juveniles, showing for each day total captures and new captures for each sex. If July 28 is chosen as the half-way point, 76.5% of the males were out of the burrow, but only 47% of the females were out. This indicates that males come out sooner than females. This same table suggests that males and females are about equally trappable with 52 male and 47 female captures. The smaller number of female captures reflects the later emergence of the females.

Juvenile Growth Rates

To figure growth rates, only squirrels that had two captures at least seven days apart were used. This is shown in Table 4. For each squirrel, weight gain in the days elapsed was figured. Weight gain was then divided by the days elapsed to figure grams gained per day for each individual. Then these values were averaged together. By separating males and females it was possible to figure average weight gains for each sex by the method described. The table shows that males gain 7.1 grams per day while females gain only 5.6 grams per day. However, most females weighed more on the first capture than did the males. Figure 3 shows that weight gain slows as the squirrel gets heavier. That may be why females seem to gain weight more slowly than males. To test this, intervals were taken in which both males and females weighed 170 to 200 grams on the earliest capture. Table 5 shows the results. Figured in this way, the males still gained faster than the females, but not quite so much. Male weight gains changed to 6.3 grams per day while female weight gains dropped to 5.4 grams per day.

Litter Size

According to Schwartz (1959), average litter size is seven. If the number of juveniles captured on the field station (34) is divided by the number of females that were captured with any regularity, the average is 6.8.

Activity

Time of activity was not recorded in detail. It was noted that the squirrels seemed to be most active during times of the day when it was warm and sunny. Squirrels were sighted as early as 7:30 a.m. and as late as 7:30 p.m. Traps set around 8:30 a.m. seemed to get as good results as those set at 7:00 a.m. Although they prefer to be out when it is sunny and warm, squirrels have been seen out when it was cool and rainy. They also like to forage shortly before and after rainstorms.

Burrows

Burrows varied greatly. Most of the burrows observed in the summer of 1970 had dirt thrown out the main entrance. Burrows had from one to four entrances. The largest burrow entrance found was 83 x 79 mm and the smallest entrance was 60 x 63 mm. Observations made in the summer of 1970 showed that the main entrances are comparatively easy to find because of the large amounts of dirt thrown outside. They are usually located in medium to tall grass. Second and third entrances are the better hidden ones, having no dirt thrown out and usually with grass over them. Extra entrances were found from one to five feet from the main entrance.

Table 5: Adjusted Weight Gains of 1970 Juveniles.

MALES				FEMALES			
Weight Range	Weight Gain	Days Elapsed	Grams Gained Per Day	Weight Range	Weight Gain	Days Elapsed	Grams Gained Per Day
190-230	40	7	5.7	170-235	65	11	5.9
190-220	30	7	4.3	175-260	85	15	5.7
200-240	40	7	5.7	170-210	40	7	5.7
185-240	55	9	6.1	190-230	40	8	5.0
170-235	65	7	9.3	225-280	55	8	6.9
175-230	55	8	6.9	195-230	35	8	3.7
6.3 GRAMS GAINED PER DAY ON THE AVERAGE				5.4 GRAMS GAINED PER DAY ON THE AVERAGE			

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PRAIRIE IN PLANNED LANDSCAPE

By

David A. Kropp, Landscape Architect
Route 1, Plainfield, Illinois

ABSTRACT

Prairie is being reconstructed as a landscape feature for residential, industrial, and public buildings. Both botanical literature and prairie remnants are studied to ensure that the species used in reconstruction represent the historic local prairie. All of the prairie plants used in landscape planting are grown from seed. By the second growing season the prairie planting has become a self-maintaining community. Reconstructed prairie usually contains thirty to forty species of grasses, forbs, and shrubs. These prairies provide pleasing landscapes, educational possibilities, and, most important, they constitute refuges for local strains of endangered species. Slides illustrate the use of prairie on residential and industrial properties.

A RATIONALE FOR THE USE OF PRAIRIE SPECIES IN ROADSIDE VEGETATION MANAGEMENT

By

Arthur H. Ode

Milwaukee County Park Commission
Whitnall Park, Hales Corners, Wisconsin

ABSTRACT

The roadsides of America represent a tremendous potential national resource in wildlife habitat and natural beauty that is as yet largely unrealized. Modern highway engineers recognize that esthetics, highway efficiency, and safety can be combined. Landscape architects have been enlisted to utilize plant material to create safer, more appealing roadsides. Although no one physiognomic type of vegetation can accomplish all the necessary goals--trees, shrubs, grasses, and forbs all having their uses--mowed grass has been utilized primarily, although expensive to maintain, because stereotyped opinions on esthetics and a lack of imagination and adventuresome spirit.

Prairie vegetation exhibits many of the functional qualities of both mowed grass and shrub vegetation. Its herbaceous nature avoids the collision hazard of trees, yet functions as a sound, sight and dust barrier. Needing little or no mowing, it substantially reduces maintenance costs. Esthetically, it is unequalled.

Artificial prairie establishment is economically feasible, comparing favorably with other vegetation types in planting costs. Prairie grass seed is commercially obtainable at reasonable cost, and forb seed can also be obtained with some ingenuity. Numerous artificial prairies attest to the feasibility of such establishment throughout the original range of native prairies. The prospect of turning vast areas of currently sterile public domain into unsurpassed natural beauty is truly thrilling, and completely feasible.

The magnitude of roadside potential for wildlife habitat and natural beauty is indicated by our 800,000 acres on our Interstate Highway system alone (Highway Research Board, 1959). Twenty million acres of roadside and other rights-of-way exist in the Eastern United States alone (estimate by Egler, 1953). Whether the potential is realized depends entirely upon the adoption of sound policies of roadside vegetation management. Right-of-way vegetation management is an integral part of modern land management philosophy, and represents manipulation of resources for practical ends. Egler points out that the disciplines of forestry, range management, wildlife management, soil conservation, and watershed management are closely allied, and it is influenced by the academic subjects of ecology, phytosociology and geobotany.

Some planting of trees and shrubs and hedgerows has been evident since ancient times, but it has become a subject of study and controversy only with the advent of high speed automobiles. In one of the first comprehensive studies of the then new art of roadside landscaping, Gubbels (1938) stated, "The expense of roadside planting is in no sense additional expense; its cost will be returned many times in the economy of maintenance. Planting is, and should be considered, an insurance policy taken out on the stability and permanence of the roadside, and on the very foundation of the highway itself. It is to the road what paint is to the house; it preserves and at the same time improves the appearance."

Egler (1953) propounded several theories which have formed the basis for the roadside and right-of-way vegetation management practices throughout the eastern half of the United States. He observed that in forested (or formerly forested) regions, the primary function of rights-of-way and roadside vegetation management was stopping plant succession short of reforestation. Observing the usual phytophysiognomic development on disturbed land from annual weeds, to grasses and forbs, to shrublands, and finally to various stages of forests, he showed that management could choose between the second and third successional stages. He proposed the

selective use of herbicides in removing unwanted invaders, and considered this a necessary, repetitive maintenance procedure. He also theorized that most observed plant succession on disturbed areas was a result of development from propagules existing in the soil, and therefore was not true succession in the ecological sense of invasions. He purported that once a particular "successional" stage was eradicated, a quite stable flora remained, relatively resistant to invasion by other physiognomic types, particularly shrubs, which he considered very resistant to tree invasion. Egler emphasized that regardless of the esthetic effect desired, or the vegetational type maintained, the primary safety needs of the highway department and motorist must be met. He also stated that noxious weeds, insect pests, and fire hazards must be controlled.

Although Egler's ideas are still sound management techniques where shrub vegetation is desired, additional roadside vegetation management principles have since been established. The planning of the Interstate Highway system included detailing roadside landscaping policies. In general, the aim was to conserve landscape features and values, to avoid monotony and over-standardization, to minimize the detrimental effects of road building, and to create an attractive and appealing facility (Op. Comm. 1961, Dept. of L.A., Ohio, 1962). Specifically the purpose of plantings are to (1) prevent erosion, (2) serve as a warning of approach to various objects, (3) provide screening of unattractive sites, (4) serve as traffic guides, (5) provide headlight screening, (6) substitute for fencing, (7) provide a noise barrier, (8) eliminate mowing, (9) control blowing snow and sand, (10) prevent stream erosion, (11) frame views, (12) provide a crash barrier, (13) improve appearance, and (14) provide shade. These principles apply, in greater or lesser degree, to most other roadsides.

Four basic physiognomic types of plant material are considered in roadside vegetation manatement: trees, shrubs, grasses and herbaceous flowers. Obviously, no one type can serve all the above-stated purposes, while, conversely, they may overlap in their functions. Trees best provide shade and frame views, yet are hazardous or impractical when improperly located (Wis. Nat. Res. Comm., 1967). Shrubs may screen headlights, substitute for fencing, provide noise and crash barriers, or prevent erosion, yet like trees are difficult and expensive to plant, to mow around and to maintain, and probably cannot be considered practical on a large scale despite much money spent on such plantings today along the interstates. Extensive research on shrub species suitable for roadside planting has led to several extensive available lists (Egler 1953; Wis. Nat. Res. Comm., 1967).

Grasses provide little in the way of screening or barriers, but do provide erosion control, and some esthetic appeal. Although mowing is a relatively uncomplicated maintenance procedure, it is very expensive (Hwy. Res. Bd., 1959). Herbaceous flowers with their obvious esthetic appeal, have sometimes been tolerated in roadside vegetation management, but they have seldom been encouraged, or actively established, except in formal boulevard plantings, which are necessarily limited in scope. Blanket herbicide spraying of grass areas eliminates wildflowers, and creates an uninteresting, often undesirable monotype. Periodic selective brush spraying (Wis. Nat. Res. Comm., 1967), if combined with a minimum of mowing, can encourage some wildflower reproduction, but such is seldom the case (Egler, 1953). An exception is Texas, recognizing the advantage to tourism of its spectular roadside wildflowers (Texas Highway Dept., 1970).

In much of the forested Eastern United States, some version of Egler's selective herbicide control for woody species, coupled with modern landscape design and turf management practices, would probably go far toward meeting the functional and esthetic needs of roadside vegetation development. Throughout much of the Midwest and Southwest, however, an entirely different concept of roadside vegetation management seems entirely feasible, and highly desirable,namely the establishment of artificial communities of prairie plants. Research during the past thirty years, notably at the University of Wisconsin, has proven that artificial prairies, with their great botanical diversity and unrivaled beauty, can be established (Greene and Curtis,1953 ; Cottam and Wilson, 1966; Anderson and Cottam, 1968). More recently, prairie restoration experiments by the Milwaukee County (Wisconsin) Park Commission indicate that such artificial prairies are economically and practically feasible (Boerner Bot. Gard., 1969). Experimentation in roadside use of prairie plants has also been undertaken by several Iowa highway departments (see Landers, 1970). There has been much additional, albeit unofficial, interest in such use of prairie species in other Midwestern states.

The prairie of the pioneers, characterized by the "paucity of shrubs, (and) the absence of trees," by tall, waving grasses, and beautiful herbaceous flowers (Weaver,1954) could serve ideally in roadside management, replacing traditional, high-maintenance bluegrass turf areas with drought-resistant stable vegetation.

Native prairie remnants are recognized (Wis. Nat. Res. Comm., 1967) as "... an especially attractive type of roadside cover." It is also excellent wildlife habitat, particularly for nests or dens, cover and food of gallinaceous birds and small mammals. The Committee recommended its preservation in roadside vegetation management, and detailed appropriate management practices, including burning at a three or four year interval. Unfortunately, such native prairie remnants are few in number, and are of course nonexistant on expressways and other roadways whose embankments and roadsides have undergone extensive grading or use of herbicides. Artificial prairies, established through direct seeding or prairie species, represent a practicable method of extending the ideally suitable prairie community into the largely unesthetic, uneconomic biological deserts which are our modern roadsides (Ode, 1968).

It is probably impossible to create a prairie in a strictly scientific sense. The phytosociological complexities cannot be immediately, if ever, reproduced. Any artifically established prairie will undoubtedly be depauperate in species, since procurement of some is difficult. And, since prairie was not studied scientifically until most of it was eradicated or highly altered, it is perhaps impossible to know exactly what it was, and therefore impossible to exactly recreate it. For all but the ecological purist however, an approximation of prairie can be established for roadside vegetation management and other related purposes.

Prairie species seed can be obtained from local prairie remnants, from many botanical gardens, and from some commercial sources. If seed is carefully removed when ripe, no damage is done to the plant. Permission for seed collecting must of course be obtained, particularly if the area involved is a scientific preserve. Several years after the establishment of a new artificial prairie tract, it in turn serves as a seed source for new establishment areas.

Many botanical institutions will provide seed of prairie species for other institutions and public agencies. Even though many botanical gardens may not have a prairie, per se, individual prairie species may appear on seed exchange lists. Commercial seedsmen, particularly those specializing in wildflowers and perennials, are a good potential source for the more showy, ornamental, species. When obtaining species from commercial sources, care must be taken to assure that they are true to name. Horticultural hybrids must, of course, be avoided. Grasses form the bulk of any prairie population, and seeds of the species dominant in most prairies can be obtained from commercial seedsmen specializing in range and forage grasses. At least six seed firms sell prairie grass seeds in quantity now. The ecologist and the horticulturalist may come to loggerheads over the use of commercially obtained plants and seeds in prairie restoration. Many ecologists frown upon introducing ecotypes from other areas into a local population, feeling that the resulting mixture will not be representative of a "native" plant community. Narrowly specific ecological research, or the preservation of nearby natural relics from gene dilution may demand that only local prairie remnants be used as sources of seeds for a prairie restoration project. For general purposes, however, success in prairie establishment will be inversely proportional to the degree of esoterism involved.

Research at the Boerner Botanical Gardens (1959) shows that, at least in Southeastern Wisconsin, deep plowing, disking, and cultivation are necessary to rid the seedbed of deep-rooted perennials, which offer the most competition to the prairie species; this is especially true when planting in hayfields or pastures containing alfalfa, timothy, and other agricultural plants. On rights-of-way areas where extensive grading has taken place, seedbed preparation is identical to that done for turf grasses.

Optimum planting time may vary with the species, but when sowing a mixture of seeds, late fall or early spring will be generally satisfactory. Most prairie species require at least one winter's stratification, and fall dormant seeding eliminates the necessity of artificial stratification. However, if spring is a more convenient planting time, seeds may be stratified in damp sand, either outdoors or in a cold room, for the winter months prior to planting. Areas of a few acres or less can be easily sown by hand broadcasting, mixing the seed with a generous

quantity of damp sand to insure even distribution.

Areas too large to seed by hand can be sown with a Nisbet grass drill, designed specifically for sowing diverse range grasses, so that it will, in the words of Jim Wilson, "plant everything from feathers to pepper." We are convinced that it will, with some experimentation, sow forbs as well as grasses. This machine shows real promise in roadside management of prairie species, and other large conservation projects. The drill is manufactured by A.R. Nisbet and Sons, Co., Inc., P.O. Box 1605, San Angelo, Texas 76901. Area Soil Conservation Service offices may have information on rental units available locally. Growers such as Jim Wilson can supply more specific information on seeding rates for grasses, and other details of the Nisbet drill (see also Schramm 1970).

The majority of species sown will germinate the first spring, but most will not be recognizable the first growing season by anyone but an expert on prairie plants. Prairie species are primarily deep-rooted perennials, and root systems develop earlier and more rapidly than above ground organs. Annual weeds such as ragweed and crabgrass will present severe competition the first two years. The first growing season, the prairie should be mowed several times, to a height of six inches, to reduce the competition from the annual weeds. The prairie species will not yet be tall enough to be damaged. A rotary mower, rather than a sickle-bar, should be used. Such mowing may also be necessary the second year, depending upon the vigor of the prairie seedlings. Ability to identify vegetative prairie plants is helpful, at this juncture, to determine whether the prairie plants are tall enough to be injured by mowing. If in doubt, and the annual weeds are vigorous, mow at about one foot (see Schwarzmeier, 1970).

The use of fire as a management technique is probably desirable and even necessary by the third year after sowing. Fire reduces woody invasion, removes excessive litter, and weakens bluegrass sods. Areas under long tillage may not have a bluegrass mat, but old pastures or lawn areas may present this problem, even if they have been plowed and disked. Burning can be done in either late fall or early spring. Most prairie species are warm season plants, hence will be dormant and thus remain undamaged by management fires. Many weed species, on the other hand, are early and late cool season plants, and will be inhibited by the proper timing of fire as well as by greater drying of soil after the mulch is burned off. It has become standard practice in prairie management to burn at least as often as every three or four years.

Fire may present problems in some locations, and care must always be exercised to backfire properly, and adequate personnel must be present to control any emergency. The procedure is not as problematical as may be imagined, however, and in most cases is neither difficult nor expensive. On small areas, or long narrow strips such as road shoulders, a burn is quite easy to control, will not produce much smoke, and should present few problems. If burning is irrevocably ruled out by higher authority in roadside management or other public agency projects, a yearly, late fall mowing will definitely help to control woody species. The judicious use of 2,4-D and related herbibides in controlling volunteer trees and shrubs may also be considered, but many prairie species are highly vulnerable to herbicide, requiring spot application by a botanical expert. There is a definite need for more research into the use of prairie species and their management. The relative inflammability of prairie vs bluebrass from thrown cigarettes needs study also.

The many economic factors involved in prairie establishment is another prime research subject. Several factors of intrinsic economy of establishment and management are, however, self-evident.

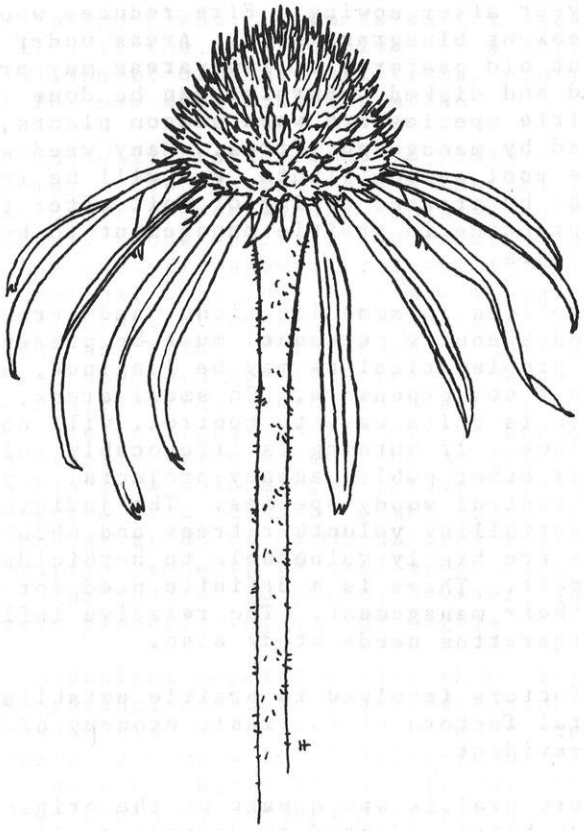
First, in areas where prairie was a part of the original vegetation, reintroduced prairie species are better adapted to prevalent climate and edaphic conditions, and are relatively trouble free and stable.

Second, in newly initiated roadside, parkway, and park development projects, the original site preparation for prairie species is very much the same as for commonly used grass species, and presents no additional cost. Seed procurement and sowing costs of prairie species may be somewhat higher than for other species, but not prohibitively so, and these costs undoubtedly will be reduced as volume production and mechanization increase.

Third, where prairie replaces grass maintained by mowing, mowing costs are reduced sixty percent or more. Far fewer man and machine hours are needed to maintain established prairie, and lawn and horticultural and farm weeds cease to be a maintenance problem as the prairie community becomes well established.

The cost of training highway personnel and obtaining advice or special machinery can be reduced as more institutions, including schools, get on the "prairie bandwagon." Quicker methods of restoration will help win over the skeptics and make it less necessary to exclude from prairie restoration the many rights-of-way that are likely to be re-graded with future highway expansion in the next two decades.

The beautiful prairie community offers tremendous opportunities for combining esthetics and diversity with economy in parkway, park, right-of-way and roadside vegetation management. But it will take some salesmanship by those of us who care about it.



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THE USE OF PRAIRIE GRASSES AND FORBS IN IOWA ROADSIDE AND PARK LANDSCAPES

By

R.Q. Landers

Department of Botany and Plant Pathology
Iowa State University, Ames, Iowa

An attractive roadside, blending into the mood of the surrounding landscape, ever changing in form, color and texture, is a desirable feature of an interstate highway system or a scenic road through a park. The tidy appearance of a lawn, appropriate at intersections and other heavy use areas, might give way in another place to the functional beauty of crownvetch and birdsfoot trefoil, unmowed and rank, holding onto a steep bank. In yet another place a uniform stand of smooth brome or the rugged mixture of original prairie grasses and forbs grows thick and colorful along a deep backslope. The prairie species, because of thousands of years of adaptation to the Iowa climate, are ideal subjects for use in lanscaping; however, their value has been recognized only in the past few years. What do we know about them? Can they be established and maintained easily, kept free of diseases and weeds, control erosion, be used for wildlife, and are they really attractive?

Our background with establishment of prairie species began in May 1965 when seeds of more than 65 species collected by hand from native prairies and railroad rights-of-way in Iowa were planted. Some plots were kept weed free, others were planted to a cover crop and others were left in weeds. Very different levels of early establishment occurred because of differences in germination and the effects of weeds; however, by the end of the first growing season several species had been established relatively independent of weeds and cover crops. By the end of the third growing season the annual weeds that had once dominated the plots were stunted or absent, and the prairie species were in full control of the site.

A large-scale planting of prairie grasses was made in late May 1967 at the Loveland Overlook on Interstate 80 in western Iowa as the start of a three year project funded by the Iowa State Highway Commission. Three mixtures based on heights of the component species were used (Table 1). Soil conditions were rather uniform for the 9 acres planted to these mixtures because of the deep loess deposition on the site. The short mixture was planted adjacent to the parking area near the crest of the overlook and was the only mixture which was mowed. K-31 fescue withstood severe trampling for two years; finally, it, buffalo grass and perennial ryegrass were restricted to more protected parts of the site. The medium and tall mixtures were planted in wide bands away from the crest where excellent establishment was obtained. Striking replacement of weedy species occurred during the second and third growing seasons. By July of the third year the medium and tall plantings looked like pure fields of waving grain, the wheatgrass dominating the medium mix and the Canada wildrye dominating the tall mix at the time. A striking example of weed control was noticed. In an area of about two acres where 65 musk thistles were growing in 1968, five could be found in 1969 and none in 1970. The natural competition of the prairie species alone had brought this species under control without mowing, spraying, or hand-chopping in this deep loess soil at the same time the pasture across the fence was heavily infested with the thistle.

Additional plantings were made in 1968 in rest areas in central Iowa along Interstate 35 to determine whether species could be used in areas of poor soil or subsoil exposures. Mixtures and single species were planted in 1/30 acre plots on coarse subsoil. One site was too severe, and regrading was necessary following a heavy downpour. The plots were lost but not before seedling counts could be made on the level portions and ridges between the small erosion gullies. Excellent establishment of sideoats grama, switchgrass, Indian grass and a few other species occurred with very little weediness. The topsoil and the weed seeds it contained had been scraped from this site in the process of grading. It was obvious that any new planting could not have prevented gully formation under these extreme conditions, but it was also obvious that a combination of prairie species would have established easily on the site under normal conditions.

We now have five years of observations on prairie species as roadside cover. Additional plantings are still being made. More than 130 acres were planted to prairie grasses in Iowa this year, 80 acres along primary and secondary roads, 10 at the national headquarters of the SCS, and 40 at a new industrial plant. During the first two growing seasons of a prairie planting, its appearance is weedy, untidy, and not conducive to good public relations in a region where mowing is the accepted practice. Most weedy species in Iowa are annuals, plants which live for one year only and must reproduce by seeds. Most prairie species, however, are perennials, which overwinter by persistent roots, bulbs or other underground parts as well as by seeds. The annuals have the advantage until the root systems of the perennials begin to occupy the entire soil and to crowd them out. By the third growing season, especially in the fall when colors appear in the prairie stems, one can see the dominance of the taller grasses and forbs controlling the weeds and adding a new dimension to the roadsides. This taller, rugged, patterned growth of the prairie species is especially fitting for Iowa, an original prairie state.

This interest in the prairie is not only for weed control and appearance; for the tall grasses offer a dependable source of nesting cover for pheasants and cover for other wildlife in a region where hayfields, oats and fence rows are disappearing as more corn and soybeans are planted. With prairie species in control it is probable that mowing of backslopes can be dispensed with entirely except where safe lines of vision are nejessary at intersections. This amounts to a large saving in maintenance costs where it has been the practice in the past to mow all the way to the fence. Other species which have been used very successfully in Iowa as standard plantings (e.g., crownvetch, smooth brome, K-31 fescue, and alfalfa combinations) receive one or no mowing at all without showing excessive weed invasion; however, it is likely that effective public information will be necessary to convince people that mowing can be reduced and that the taller prairie species are beautiful. Many people still regard an unmowed or an unknown plant as a weed, and a colorful prairie species may suffer because of a remotely similar looking pest of the fields and pastures. Another problem is the lack of seed sources for the colorful flowers of the prairie, a situation which could soon be remedied by the appearance of commercial seed companies interested in native plants. Many native grasses are available already.

Successful establishment of prairie grasses and forbs has been achieved by scattering seed by hand on ground that has been rototilled or disked followed by packing or dragging. Best establishment has occurred with June plantings at seeding rates of about 20 pounds pure live seed (PLS) per acre (Table 3). With the Nisbet grass drill, this amount can easily be reduced by one half.

It would be difficult to find a better group of species for Iowa landscapes than the original prairie grasses and forbs. It was this combination of grasses, legumes composites and other prairie plants which built the rich Iowa topsoil and protected it until it was plowed. With the large number of different kinds of plants to select from there is little chance of a destructive disease spreading through a planting. It provides a variety of food and cover for wildlife. Fire, once a natural phenomenon on the prairie, could be introduced under prescribed conditiins to control woody species such as red cedar, mulberry, and elm.

The prairie species seem to respond with added vigor and reproduction during the year following such an event. Therefore, from the standpoint of weed control, natural beauty, wildlife conservation, and economy of maintenance, it appears that mixtures of prairie grasses and forbs can be added to the list of plant materials which should grace Iowa roadsides and park landscapes in greater abundance in the future. One landscape architecture firm in central Iowa believes in the opportunities of prairie landscaping so much that it has surrounded its building with several acres of prairie plantings. An excellent stand was obtained from seed and transplanted material from our experimental plots.

Table 1: Mixtures of Grass Species, Loveland Overlook. (See Table 2 for Natives).

A-Short	B-Medium	C-Tall
Blue grama	*Sideoats grama	*Big bluestem
*Buffalo grass	Little bluestem	Sand bluestem
Sand dropseed	*Intermediate wheatgrass	Sand lovegrass
Bluegrass	Tall wheatgrass	*Switchgrass
*K-31 fescue	*Slender wheatgrass	*Canada wildrye
*Perennial ryegrass	Crested wheatgrass	Russian wildrye
		*Indian grass
		*Alkali sacaton

*Successful establishment at end of second growing season.

Table 2: Selected List of Prairie Species in Iowa Plantings.

Grasses	Forbs
Little Bluestem (Blaze; native Nebr.) Andropogon scoparius	Showy sunflower Helianthus laetiflorus
Big Bluestem (Pawnee) Andropogon gerardi	Saw-tooth sunflower Helianthus grosseserratus
Switchgrass (Blackwell; Path finder) Panicum virgatum	Yellow coneflower Ratibida pinnata
Indiangrass (Holt; Nebr. 54) Sorghastrum nutans	Purple coneflower Echinacea pallida
Canada wildrye Elymus canadensis	Compass plant Silphium laciniatum
Side oats grama (Trailway) Bouteloua curtipendula	Bush clover Lespedeza capitata
Buffalo grass Buchloe dactyloides	Tick trefoil Desmodium canadense
Slender wheatgrass Agropyron trachycaulum	Purple prairie clover Petalostemon purpureum
	White prairie clover Petalostemon candidum
	Stiff goldenrod Solidago rigida
	Tall goldenrod Solidago altissima
	Rattlesnake master Eryngium yuccifolium
	White Heath aster Aster ericoides
	Fall aster Aster laevis
	Black-eyed Susan Rudbeckia hirta

Table 3: Native Grass Mixtures (Tentative for Iowa).

Basic Tall Mixture - for areas which will not be mowed, wet areas, deep soils and areas where plant height of 4-5 feet is desired.

	Pounds pure live seed per acre
Big bluestem	8
Indian grass	8
Switch grass	4
Reed canary grass	1
	21

Basic Medium Mixture - for areas which will not be mowed, on dry sites or shallow soils, and areas where plant height of 2-4 feet is desired.

	Pounds pure live seed per acre
Little bluestem	5
Side oats grama	6
Canada wild rye	8
Slender wheatgrass	4
	23

RANGELAND PRODUCTIVITY AND COMPOSITION DATA STORAGE, RETRIEVAL, AND USE

By

Thomas N. Shiflet
Range Conservationist
Soil Conservation Service, Lincoln, Nebraska

ABSTRACT

The Soil Conservation Service started in 1967 to develop a nationwide Range Resource Data Storage and Retrieval System (RDS) consisting of several segments or subsystems.

To date, most effort has been expended on the subsystem relating to Rangeland Productivity and Botanical Composition. In this segment production and composition data from soil taxonomic units, along with related locator and environmental information, will be stored in a Data Bank. Data from prairie soils will make up a significant portion of the stored information.

These data will be retrieved and analyzed by standard and special computer programs to enable the SCS to render faster, more efficient, and more scientific service to those it assists. The arranging of soils into interpretative groupings, such as range sites, is a typical use anticipated for the system. Many other uses and studies can be made when sufficient data are stored in the bank.

The Productivity and Composition subsystem will include data from rangelands (natural grasslands and savannas), grazable woodlands (forest lands that produce an understory of herbaceous plants that can be grazed without harm to the timber resource), and native pastures (lands whose climax vegetation is forest but are being managed as disclimax grasslands).

The entire system is being closely correlated and coordinated with other data systems within the SCS. Many other uses are anticipated to improve the scientific accuracy of SCS work. Illustrations of data stored in the system include comparisons of productivity data between different soils in one year and between different seasons on the same site.

RESEARCH IN THE INTERNATIONAL BIOLOGICAL PROGRAM GRASSLAND BIOME

By

Paul G. Risser

Department of Botany

University of Oklahoma, Norman, Oklahoma

Introduction: The International Biological Program (IBP) is a world-wide organization concerned with studying the productivity of biological systems in relation to man. The IBP has a number of individual project areas, each of which has a different orientation. I will talk today about the area called the Analysis of Ecosystems (AOE), which has as its objective, understanding the transfer of material and energy through ecosystems. The United States IBP is divided into six biomes: the tundra, coniferous and deciduous forests, grassland, desert, and tropical vegetation. We will consider only the Grassland Biome which has the broad objective of simply understanding grasslands. The strategies employed in our researches are to determine the driving forces making grassland ecosystems operate, the major and minor components of grassland ecosystems, the changes in magnitude of these components over time, the important processes which cause the interaction or linking of the components of the ecosystem, the important internal and external parameters, and the methods by which the plant, animal and microbial community or social interactions affect these processes.

Our experimental design is such that detailed analysis of the experimental results are used to derive information about the grasslands system's coupling of driving forces, components, and processes and how these are related to structure and to community or social interactions. We have designed a variety of initial models of total grassland systems or their components to provide a focus for our research efforts. These models represent mathematical expressions of various degrees of complexity and resolution, and many of these models include probabilistic measurements. Eventually we will translate these mathematical model statements into computer languages to permit simulation and optimization analysis.

The field studies involve two major components, the Pawnee Site or Intensive Site, and the Comprehensive Network. The Pawnee Site is a short-grass prairie located near Fort Collins, Colorado. Here a large interdisciplinary team has been established to measure as many as possible of the compartments, driving forces, parameters, and control variables in a set of stressed grasslands. The major stressing perturbation treatment is that of herbivory, imposed by more than 30 years of known light, moderate, or heavy grazing by domestic animals in replicated 128-hectare pastures. Additionally we are imposing stresses of moisture and nutrients on some replicated 1-hectare areas and plan for additional stresses concerning replacement or elimination of different biotic components of the community.

In the Comprehensive Network Sites, including most major types of United States grasslands, we assemble smaller interdisciplinary teams to focus primarily on two treatments - grazed and ungrazed by domestic animals. Thus, the Comprehensive Network program includes a subset of treatments found on the Pawnee Site, specifically zero or heavy herbivory by domestic animals. Measurements are made in both the Pawnee and Comprehensive Network Sites of both abiotic components of the system and the biotic factors. The difference is primarily a matter of degree with the effort being more intense on the former. At the present time we are accumulating a large amount of specific factual information from which ecological generalizations can be derived and we are learning the degree of spinoff we can expect from such interrelated studies. Equally important we have learned more about the kind and amount of effort needed to maintain the high degree of intercommunication and cooperation among scientists involved in this project.

Description of The Pawnee Site

The projects at the Pawnee Site involve approximately fifty senior investigators and many graduate students. A laboratory-dormitory building has been constructed with dining facilities. This building also contains a center for data acquisition from continuously monitored plots on the Site. There are six micro-watersheds which have been curbed with concrete. These watersheds are used for detailed analysis of water input and output. In addition, vegetation studies are done adjacent to these water-

ALE
BISON
DICKINSON
BRIDGER
COTTONWOOD
HOPLAND
PAWNEE
HAYS
PANTEX
OSAGE
JORNADA
First order (intensive)
Second order
Third order

FIGURE I

sheds. A large number of consumers are being studied simultaneously and the results of the producer, consumer, and decomposer studies are being related to each other and to the abiotic components of the environment.

Description of The Comprehensive Network

Figure I depicts the location of the ten Comprehensive Network Sites. These Sites are termed either second or third order Sites based on the number of trophic levels which are being studied at the particular Site. A considerable amount of planning has gone into the sampling procedures;so they are roughly equivalent from site to site. The data from all the Sites is sent to Colorado State University where initial analysis and summary takes place. The data are then returned to the principal investigator at each Site and a copy is retained in the central data bank.

Although not all grassland types are equally represented, the Network Sites are distributed to include examples of the palouse, annual, mountain, tall, mixed, and short-grass prairies (Table I). At all Sites, the above-ground and below-ground biomass are being sampled at two-week or monthly intervals. At most sites insects are being collected by a trap mechanism for identification and for quantification. In addition, the decomposers are being studied both by standard laboratory techniques and by measuring the decay rates of specific substances. A traveling team is studying the bird populations on most of the Network Sites. Similarly, several teams are studying the small mammals across the Comprehensive Network. Since each Site also makes basic meterological measurements, intra- and inter-site comparisons can be made concerning the relationships between biotic components and between abiotic and biotic components. The results from the Comprehensive Network are also being integrated with the detailed studies from the Pawnee Site.

Conclusions: There have only been two field seasons on the Intensive Site and one in the Comprehensive Network; hence an evaluation of the Program would be premature at this time. However, some very encouraging aspects have developed during the short time the Grassland Biome has been operational.

Prior to initiating field studies, a number of meetings were conducted in which biologists from all disciplines discussed the literature, techniques, and desirable experimental designs. During these meetings there was considerable dialogue between men interested in the abiotic components, producers, consumers, and decomposers. An understanding of the sampling problems at each trophic level was obtained by all members of this discussion group. The material result was a Technical Report which reviewed and synthesized a large part of the grassland literature.

We are now accumulating a tremendous amount of specific factual information. A great deal of planning was done prior to field work and most of the data appear to be the kinds which are needed. The results of these studies,which will eventually appear in the literature,have begun to appear in a series of over 50 preliminary Technical Reports already produced. This initial information will be utilized in planning future research. The laborious task of transferring these data into ecological generalizations and implementation of management techniques has just now begun.

A successful program of this size requires a considerable amount of cooperation and team effort. It has been most gratifying to see the extent to which a large number of scientists have been able to pool their efforts and talents to develop such a program.

Table 1. Characteristics of Comprehenisve Network Sites and the Pawnee Site

Site	Elevation (m)	Major Vegetation	Grassland Type	Phenology (lilac bloom)	Annual ppt (cm)	Soil
ALE	520	Agropryon spicatum Stipa comata	Palouse	May 1	30	glaciofluvial and aeolian
BISON	980	Festuca scabrella Festuca idahoensis	Palouse	May 20	33	Chernozem
BRIDGER	2,320	Festuca idahoensis Agropyron subsecundum	Mountain	July 1	61	--
COTTONWOOD	850	Agropyron smithii Stipa virdula	Mixed	May 20	38	silty clay
DICKINSON	850	Stipa comata Bouteloua gracilis	Mixed	May 30	41	flasher loamy fine sand
HAYS	610	Andropogon scoparius Andropogon gerardi	Mixed	April 25	58	Armo, immature, rocky
HOPLAND	300	Avena fatua Hordeum jubatum	Annual	April 5	94	--
JORNADA	1,340	Bouteloua eripoda Sporobolus flexuosus	Desert	April 1	23	alluvial fill
OSAGE	380	Andropogon gerardi Panicum virgatum	Tallgrass	April 20	94	Labette, silty clay
PANTEX		Bouteloua gracilis Aristida longiseta	Shortgrass	April 15	53	Pullman silty clay loam
PAWNEE	1,430	Bouteloua gracilis Buchloe dactyloides	Shortgrass	May 10	30	alluvial plains, high in clay

MICRO-EVOLUTION OF CANADA MAYFLOWER BY CLIMATIC CHANGE AS SHOWN BY GEOGRAPHIC DISTRIBUTION INDICATING POST-GLACIAL PRAIRIE EXTENSION

By

David F. Grether

Department of Biology
St. Cloud State College, St. Cloud, Minnesota

ABSTRACT

The pubescent variety of the Canada mayflower (a forest herb) has a distribution which is somewhat indicative of the same post-glacial climatic changes which also caused the expansion of prairies in North America.

Methods and Results

The Canada mayflower (Maianthemum canadense Desf.) and a western variety (M. c. Desf. var. interius Far.) were described by Fernald (1914) as differing in that the western variety is pubescent while the typical eastern species is completely glabrous. The difference between M. canadense and var. interius are listed by Butters (1926; 1927) as differences in pubescence, leaf form, form of inflorescence, texture, veining and margins of leaves, the anatomy of the rhizome and slightly in flower and fruit.

In this investigation, examination of about 20,000 specimens from several herbaria (Chicago Museum; Gray; Univ. of Minn.; Missouri Botanical Garden; University of Nebraska; U.S. National Museum; Oberlin College; Rocky Mountain; Univ. of Wis.) and many mass collections from various parts of the range reveals a distinct type in the western end and another one in the eastern end of the range. In the area between the two extremes, many intermediate types show an intermingling of characters.

The plants examined were tabulated using the following characteristics: A,B,C, and D are more characteristic of var. interius, while a,b,c and d are more like the more eastern M. canadense.

A = Pubescent	a = Glabrous
B = Ciliate leaf margin	b = Non-ciliate margin
C = Weak cross veins	c = Strong cross veins
D = 3-7 strong longitudinal veins	d = Longitudinal veins not prominent

Each plant was grouped with others in geographic sections, with each character plotted separately for North America. There is some variation and overlapping of characters, but generally the mapped characters indicate an eastward extension of plants with at least some of the interius characters.

Since other species also exhibit pubescense or hairiness at one end of the range and lack it on the other (Angelica atropurpurea; Lupin us perennis; Krigia biflora; etc.), this particular characteristic was chosen for further investigation. Disregarding taxonomic tags, each individual plant was examined for presence of hairs and grouped with those from particular geographic area. The map of the range was marked off in 120-mile squares, and all the plants, both pubescent and glabrous, located within a square were used to calculate the percentage numbers on the map (Figure I). Pubescence ranges from full on both surfaces to just a few hairs on the lower surface near the petiole. The heavy lines on the map separate the regions of 100% wholly glabrous plants from those of pubescent and partially pubescent populations.

Discussion

In the interpretation of the differences between the two varieties, Butters accepted them as distinct taxonomic entities without questioning why they might have become that way. He states, "...in view of the complete intergradation of the two forms over a relatively large portion of their range it seems necessary to maintain them in the status which Fernald assigned to them, namely as well-marked geographic varieties--but certain peculiarities in their geographic distribution have convinced

the author (Butters) that the case is really more complicated than this simple statement would imply." He further states "in Minnesota true Maianthemum canadense is essentially a plant of the northern evergreen forests, and var. interius a plant of the more southern deciduous forests." He mentions the possibility of their being ecological forms but dismisses the idea because they are often found co-mingled along the borders of their range. He also hypothesizes that, "at an early date, probably at the beginning of the Pleistocene, the ancestral species had already segregated into an eastern glabrous, and a western pubescent form. During the Pleistocene glaciation the species was disrupted, the eastern form surviving in the southern Appalachians and the region east of that chain, possibly in the unglaciated regions of Wisconsin and the adjacent states, and possibly also farther west beyond the western border of the ice. It seems rather strange that M. canadense, the species which occupies the most compact geographical area (compared to M. bifolium and M. dilatatum), should thus show the greatest tendency to vary. This is probably in some way connected with the violent changes of environment to which it was subjected during the Pleistocene period." The formation of a pubescent variety in the first place would seem to suggest some advantage for possessing pubescence and this advantage may also explain the present distribution.

The development of pubescence may have started with the Rocky Mountain revolution which produced the prairies to the east of the mountains with a gradual selection of more and more pubescent individuals and elimination of glabrous ones in the areas close to prairies. Collections made in an abandoned drainage channel of Glacial Lake Wisconsin near Wisconsin Dells show evidence of ecological influence on distribution. These channels,cut through Cambrian sandstone, are about fifty feet deep with steep cliffs on both sides. They were cut at the time of the overflow of Glacial Lake Wisconsin after the morainic damming of the Wisconsin River. The area at the base of the cliffs is more humid and shady than the area at the top of the cliffs (Figure II).[1] Plants on top of the cliffs, in open shade under pines, are mostly pubescent, while plants in the hardwood forest in the bottom of the channel and on the slope up to the cliff tend to be more glabrous.

The advantages of pubescence on leaves has been variously documented; with some authors, pubescence is said to aid in transpiration, while others believe it hinders transpiration. Leaf hairs (trichomes) have also been shown to be absorbers and non-absorbers of moisture (Winkler, 1964; Inamden, 1967; Banera and Wernsman, 1966; Amelunxen, 1965). It may be possible that this function might change during the life of the plant. It is also possible that the pubescence on the surface of the leaf may collect and absorb dew during the cool part of the day, and later form a microclimatic transpiration-inhibiting zone on the leaf surface when it is hot and dry. Whatever the function of hairs in M. canadense var. interius, interius seems to fit the prairie influence concept as shown by the distribution map (Figure I).

Since prairies are found in the dry parts of the country, plants growing near the prairie, even if they are not strictly prairie plants, would seem to have to adapt to somewhat drier climatic conditions. Moreover, during the last 12,000 years there have been several shifts in worldwide climate causing prairie expansion during warm dry periods, and a return expansion of hardwoods into prairie regions during more moist periods (Curtis, 1959; Cushing, 1965; McAndrews, 1967; Russel, 1941). There is evidence in pollen records, bone deposits, the range of pinnated grouse, and other sources, that prairies in North America reached the Atlantic coastal area at least once. During normal climatic conditions the reason for pubescence or lack of it may not be apparent (like the lobed fins of the Coelocanth), but when change of climate occurs, and dry prairie air moves into the forested areas with diminishing rainfall and gradual disappearance of trees, pubescence could have provided the plants with slightly better survival characteristics. Thus, although Canada mayflower is a forest species unable to survive in direct sun (Hall, 1955), it may nevertheless be a good indicator of past prairie range. In fact, it may be more useful than a true prairie species which would have succumbed to shade each time the forest returned. The fact that it does have more pubescence in the drier parts,or what would have been drier parts, of its range, makes a prairie climate influence on the forest flora a reasonable hypothesis worth investigating in other species. Because of the long life of Maianthemum - spreading vegetatively once established for decades and perhaps centuries, persisting in cliffs and diverse micro-environments - it and similar plant species may prove to be especially valuable as historical indicators because their population evolution can be expected to have lagged behind climatic and vegetational changes.

1 See Photo Section

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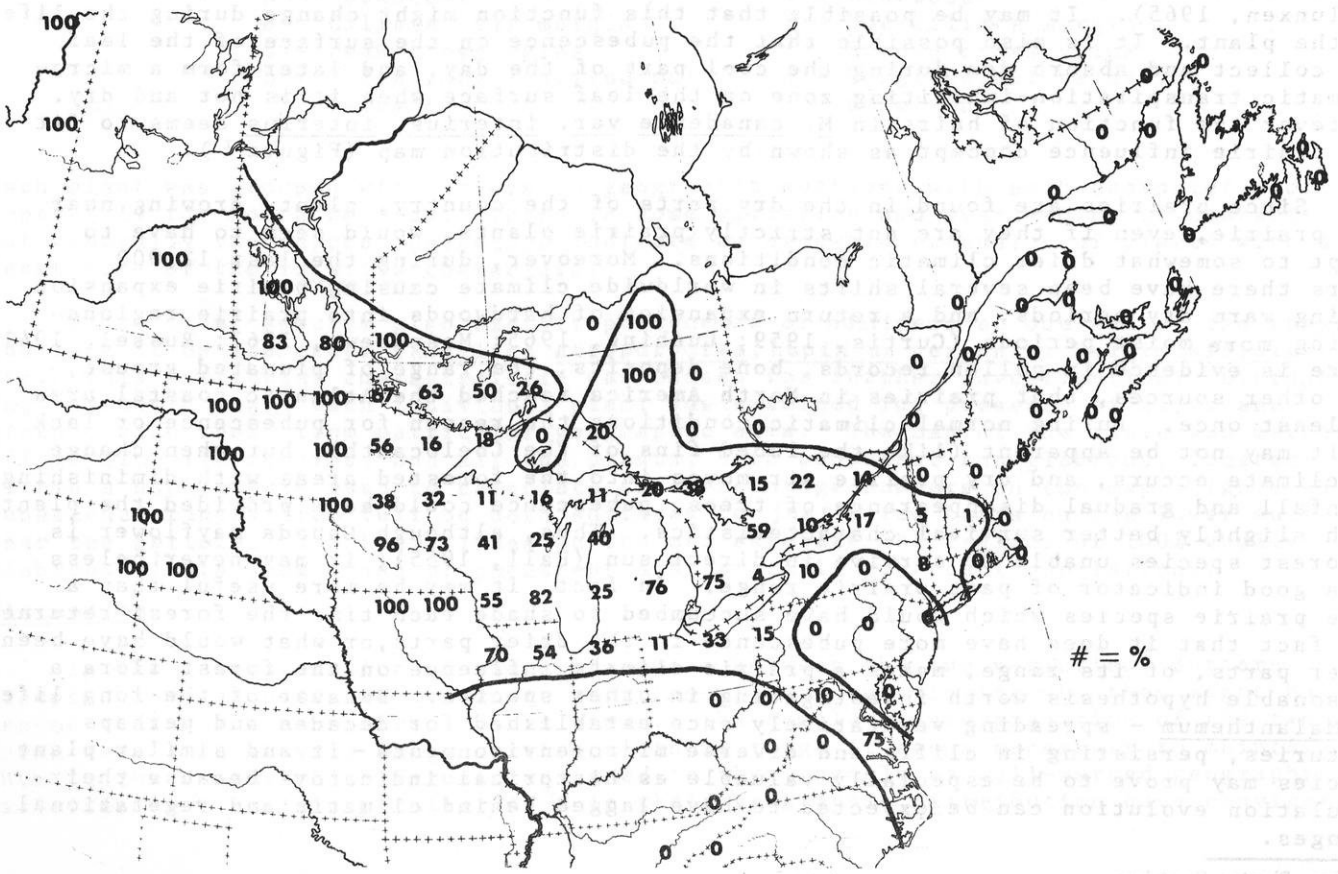

PANEL ON PRAIRIE IN EDUCATION

A FOREST FOR LEARNING

By

Virginia Kline

School Forest Naturalist
Curriculum Department, Madison Public Schools
545 West Dayton Street, Madison, Wisconsin

The Character of Madison's Outdoor Education Program

Each day in spring and fall the yellow school buses gather up a hundred or so excited Madison school children and their teachers for a field trip to the Madison School Forest. It's a day long anticipated and many an anxious eye has checked the morning sky for recalcitrant clouds. On the way a trained naturalist-guide boards each bus to join the children for the twelve mile trip. With the aid of the bus loudspeaker system the naturalist points out interesting birds, plants, geologic and historic features along the way - helping to set the tone of observation and learning to be continued along the Forest trails. Contrasts are noted: between man-managed fields with little diversity and natural areas with great diversity, between birds seen in open country and those in the forest, between layered angular rocks in a roadside quarry and rounded glacial cobbles used to build a retaining wall, between the glaciated landscape at Madison and the steep hills of the "driftless" area as the bus nears the Forest on a road whose roller coaster contours bring enthusiastic "oh's!" (The cooperative bus driver drives for the full effect).

Additional naturalists await the bus at the parking lot so that each class will have a guide as the children explore some of the seven-mile trail system which winds through the Forest. Discoveries during the 1 1/2-2 1/2 hour hike will vary according to the age and interest of the children, the emphasis planned by the teacher, the season, and the unforseen "happenings" typical of an outdoor exploration. A hawk soaring overhead, an active spider web, deer tracks in the trail, a grouse drumming- such current events take precedence over planned observations! Flexibility is a key to success, as is the naturalist's skill in relating such happenings to the ecology of the Forest. Hopefully each child will benefit from the innate pleasurable human response to the natural environment; will increase awareness through use of his senses; and will gain new insight into the complex interrelationships between living things.

The pleasure of responding to a natural environment and the growing awareness and understanding fostered by teacher and naturalist are made available to thousands of Madison children each year through the School Forest Program. Naturalists and buses provided by the Board of Education are just one part of the program, which has grown continually since its inception a decade ago. At that time a generous gift of land was made to the Madison Board of Education - 160 acres of virtually undisturbed oak woods. (Since that time an additional gift has increased the acreage to nearly 300). From the beginning the Forest program has been guided with vision and expertise by its present director, Mr. Paul Olson, principal of a local elementary school and long-time active conservationist.

Work-Learn Program

Committed to the idea that the best place to teach conservation is outdoors, Mr. Olson had already organized a summer "Work-Learn" program for ninth grade boys. These boys "too old to play all summer and too young to get jobs," as Mr. Olson observes, were involved in improvement of area trout streams - fencing cattle out and installing stream structures to direct flow and stabilize banks. This work involved cooperation with the farmer-owners and the Wisconsin Department of Natural Resources. Mr. Olson wanted to add good forestry practice to the boys' experiences and had begun to work in farm woodlots. The new gift of land provided permanent forestry opportunity, and approximately half (80 acres) of the Forest was set aside for this purpose by the administering School Forest Committee. Here, closely supervised by teachers recruited for summer work, the boys learn some basic forestry principles. More important, perhaps, they learn the feel of saw and axe, the excitement of the shout of "timber!", and the sensation of aching muscles after a hard day's work. With lumber cut the

second summer the boys built the first shelter house. Each year, further structures are added for the other facets of the growing School Forest Program. Certainly an essential aspect is that, at all stages from cutting to finished buildings, the boys participate and take pride in the end result. As each part of the program has developed, Mr. Olson has obtained support from the Board of Education, plus occasional additional funds, materials or labor from local businessmen.

School Camping

In a 40-acre hilltop set aside for school camping, the Work-Learn boys have built a second shelter house, food preparation and utility building, four insulated and heated cabins to accomodate 15 to 20 cots each, and a large nature center. The buildings are located around the edges of a large mowed field suitable for active sports. Here in spring and fall two classes at a time, usually 5th or 6th grade, can spend one or two nights. Each camping group plans its own schedule, including learning expectations, recreational activities, campfire programs, food, and individual chores. Naturalists are provided for approximately three hours each afternoon, two per class, to lead exploratory hikes and conduct special studies of such topics as mammals, insects, soils, weather, plants, birds, or geology. The camping experience has been very successful, and reservations fill the entire season well in advance.

Adjacent to the campground a picturesque rocky area is available for family picnicking, with picnic tables provided by the Work-Learn boys. While the camping, picnicking, and forestry areas are modified by man's use, the rest of the Forest limits man's role to that of preserver and observer. For this large area, Mr. Olson envisioned an interpretive program for all ages of Madison children.

Interpretive Program

To launch such a program he was fortunate to meet and enlist the aid of Dr. James Zimmerman, outstanding naturalist and teacher. Dr. Zimmerman, the key person in training the necessary naturalists and increasing the environmental awareness of the teachers, has assisted each year in three ways:

1. An evening course in ecology entitled "Reading the Landscape," held once a week for twelve weeks plus field trips. Made available at low cost to the public through the Madison Area Technical Vocational College, this course has reached hundreds of people in the area, especially young and older adults and public school teachers. To encourage teachers to participate, salary advancement credits are given to recruit potential naturalist-guides from the ranks of homemakers with a variety of educational backgrounds. A few graduate students at the University of Wisconsin also serve as naturalists, and more recently high school biology honor students have worked with the camping groups. But the homemakers comprise the majority of this important resource pool. The seasonal part-time nature of the work offers mothers a stimulating outlet and supplementary income while not straining the school budget with full-time employees. The relative greater permanence of the homemaker is another advantage over students and school teachers who often leave before they can be fully trained - a matter of several years.

2. A week-long School Forest Institute in June offering a concentrated outdoor learning experience for teachers. The enrollment in this course has increased so much that several of the more experienced guides now assist with the instruction. The course is sponsored by the Board of Education. Fees charged pay for the instructors' salaries. Advancement credits are given.

3. Training for naturalist guides, originally accomplished on an informal on-the-trail basis. The need for guides for various outdoor programs in the Madison area has increased so tremendously that a cooperative training program has now been set up with the University of Wisconsin Arboretum, with the encouragement of its director, Dr. Roger Anderson. The once-weekly sessions include lectures and lab-type activities conducted by Dr. Zimmerman, several guest speakers from the University faculty, seminar studies prepared and presented by the guides themselves, outdoor study of various natural communities, and field trips to places of special ecological interest. Mrs. Rosemary Fleming, Dane County Naturalist, has assisted in coordinating this training, and does a good share of the teaching also.

Starting with one naturalist in 1961, the Madison Public Schools hire twelve part-time guides at present, and three at the new Cherokee Marsh teaching area on the opposite side of the city. The Friends of the Arboretum hire additional naturalist guides to handle visits by both local and more distant grade school classes to the Arboretum.

Instructional Materials

High-quality materials have been developed to aid the classroom teacher. Examples of these include three publications of the Madison Board of Education:

1. A comprehensive 150-page book, "Madison School Forest," written by Messrs. Olson and Zimmerman (1962). This is an excellent text for adults on the geology, ecology, history, plants and wildlife of southern Wisconsin oak forests, uniquely geared to the specifics of a well-studied site.

2. An illustrated eight-page leaflet, "What is a Tour Through the Madison School Forest?" (1969). Summarizing briefly some of the basic concepts and learning experiences possible on the trail, it encourages teachers and students to go out and see things for themselves.

3. Instructional sets which include filmstrips and guidebooks for classroom use: "Three layers of Green in the Madison School Forest" for upper elementary students and "Madison School Forest: Clues to the Past and Signs of the Future" for middle school. These sets were developed as part of a local materials project directed by Mrs. Mary Lou Peterson, and funded under ESEA Title III, in 1969-70. Preparation of a third set on the prairies is well underway.

Looking Toward the Future

A program maintains its vitality through continual growth and improvement. Future plans for the School Forest include beginning a summer camping program, and developing guidelines and materials for individual grade level experiences at the Forest. Coordination with programs developing at other sites in the area will be important. Recently the Madison Parks Department acquired 800 acres in a wetland known as Cherokee Marsh. Through a cooperative arrangement - not easily achieved - between the Parks Department and the Board of Education, an outdoor education program has been started there and is growing rapidly. In addition, efforts will be made to identify an area within a walking distance of each school suitable for outdoor education. Having such areas available would encourage more frequent and impromptu investigations of particular topics and would provide a valuable supplement to the School Forest program. The Parks Department is now interested in cooperating in this effort, thanks especially to Superintendent Forrest Bradley and Assistant Superintendent Scott Huston.

What Makes it Work?

The educational opportunities for teachers and guides and the materials developed have been mentioned in detail because it is through this approach that the children traveling in the yellow school buses experience more than an isolated "nature walk" or a tree identification exercise. The versatility of the well-prepared naturalist-guides is absolutely vital to capitalizing on the many spontaneous opportunities provided by each trip and by diverse young minds. It is essential that the guides be paid and paid adequately, since volunteers seldom stick with the training and the profession long enough to obtain the high quality of performance needed.

At the same time the size of the area and heavy bramble understory confines the very intensive use to a few trails which can themselves be rotated to repair wear and tear, while most of the forest is left completely alone to foxes, deer, owls, skunks, woodchucks, racoon, squirrels, and nearly 50 species of birds. The site is large enough to accommodate camping (40 acres), forestry (80 acres), and a large natural area (most of the rest, designated as a State Scientific Area for serious study and comparison).

This large and beautiful undisturbed site in fully rural surroundings free of any highway noise, while a remarkable asset, is possibly not essential for a meaningful program. Any reasonably natural area with diversity in plant and animal life can

be suitable. We feel the most important factors in making best use of the site selected include: (1) an able, active catalytic director with conservation sense, innovative ideas, and a good sense of timing; (2) a thoroughly experienced naturalist-ecologist to train and teach guides and teachers continually; (3) a supportive community and Board of Education; and (4) a full measure of enthusiasm and committment on the part of all those involved.

But the large fund of information assembled through the previous 20 years of University research and class use, and the sense of wonder and excitement at exploring a really sizeable natural and wild area, may prove to be equally important factors because of the impression it leaves on young minds--and on those of the adults too. Many children drag their parents out for a picnic on weekends, while parents, offered occasional Sunday public tours, have sometimes sparked additional school class trips by exerting pressure on the principals or teachers. There is always a need for improved activities designed to involve children and adults more deeply during the trip experience, and for better preparation and follow-up in the classroom, through an as-yet-unfunded full-time position of outdoor education specialist in the public schools. But the simple fact of personally visiting such a school forest or camping in it is perhaps the most important aspect of outdoor education. It may not matter that scheduling high school involvement is difficult.

If the need has been properly gauged, we can expect to see a big improvement in ecological literacy and involvement in the near future in the Madison Community of 200,000 people. Although this community is growing at the net rate of 6 people per day, the outdoor education program has grown also. Starting in 1960 with 5 class tours, 3 public tours and 40 boys in Work-Learn, it now involves some 34,000 young people a year and is spreading to a variety of natural areas in and around the city. Already we have an answer to the reaction of a buyer for the Kentucky Whiskey Barrel Industry who had almost bought the School Forest when Colonel Joseph Jackson found a donor to acquire it for Madison's schools in 1959. Returning disappointed several years later, the buyer viewed the arriving yellow buses, shook his head, and exclaimed to one of the naturalist-guides: "What a waste of good white oak!"

The Role of Prairie in The Madison Program

In three ways the story of Madison's School Forest relates to the prairie conference: First, it was the success of the school forest program that eventually led to the use of the U.W. Arboretum, including its restored prairies, for intensive youth education to supplement visits to the School Forest. Both prairie and forest mean more when studied together for an understanding of natural ecosystems and land use history. The Arboretum's naturalist position was created and patterned as a result of the success of aiding the many ecologically insecure teachers by accompanying their classes to the School Forest with experienced field naturalists. Arboretum security has benefited as much as the students from the position of interpreter who helps people appreciate, respect and protect natural ecosystems rather than vandalize or abuse them in ignorance.

Secondly, since the School Forest itself is a largely unlogged, ungrazed, transitional one-generation forest of oak following wildfire cessation in 1840, it portrays the continuum in both time and space between pre-settlement prairie and the northeastern and Lake States' climax sugar maple-basswood-elm forest. It contains on the driest sites and poorest sandy soils several prairie relics gradually succumbing to shade, and several struggling poor-quality oak stands with oak understory where succession to climax is severely retarded. On more mesic sites, even-aged, multiple-trunked white and black oaks, shagbarks and black cherries, 130 years old, surround occasional uncut, rotting open-grown white oak relics of pre-settlement prairie days.

The most protected exposures and deep-loessial soils support red oaks and invasions of sapling elms, sugar maples, walnuts, basswood, hackberry and ironwood, spreading from refugia along cliffs and the lower Sugar River Valley whose richer herb flora bespeaks protection from fire. Students can be involved in Sherlock Holmes work deducing the forest's history and future from open versus forest-grown oaks, prairie relics, sapling understory, and fire scars dating to a ground fire in 1921; observing the effects of soils and exposure on the rate of succession; and relating topography and succession and blowdown openings and logs to animal habitats.

The socio-economic influence of soil and rock types, topography, and settlement and farming are self-evident, leading to understanding of much of Midwestern ecology and training in reading the land and using the mind.

Finally, the third teaching area at Madison - Cherokee Marsh - supplements the School Forest and Arboretum in both its nature and use requirements. Located on City and State land, it is a matrix of extensive sedge meadows, both natural and disturbed, containing islands of upland oak and transitional ash-basswood-cherry forests as well as old fields, ponds, streams, fens, wet marsh, relic bogs, springs, and a silt-choked, carp-infested river. These habitats intergrade subtly in many ecotones, including small examples of virgin wet prairies.

The prairies form a focal point to tie together the Madison area and its history, ecosystem, land use and abuse, as well as demonstrating the beauty and integrity of natural ecosystems where man's impact has not been seriously or irreversibly disruptive. The area contrasts sharply with urban sprawl on one side and a busy airport on the other. The very sensitive lowlands offer the greatest challenge in developing involvements while guiding intensive class and public use so as to maintain their quality. Here the decade of experience with upland teaching areas is being brought to bear to minimize costly mistakes.

COMMENTS ON THE USE OF ARBORETUM PRAIRIES IN YOUTH EDUCATION

By

Rosemary Fleming

Dane County Naturalist and Tour Coordinator
University of Wisconsin Arboretum, Madison, Wisconsin

Arboretum prairies attract hundreds of students and youth groups each year. Trained guides lead small exploration groups along prairie trails in a direct-experience approach to learning. Participants are encouraged to listen, touch, observe, smell and compare. Many questions are posed as youngsters trace food chains, look for plant and animal adaptations, observe plant structure, and compare flowers, seeds, soils, and general composition of prairie to adjacent plant communities.

Examples of general points covered on tours include:

1) What is a prairie? What makes it different from other communities?
2) History and heritage: the prairie's importance to the present economy, and the building of early settlements.
3) Sights, colors, heights of plants; clumping, appearance, action of wind, weather, insects, birds, mammals.
4) Prairie music; sounds as related to action.
5) Composition; counting numbers of different kinds of living things, their variety, the values of diversity.
6) The relationship of prairie plants to soil building (discussed at soil pits and the experimental plots of Dr. Francis Hole).
7) Plant adaptations for survival - structure, blooming times, heights, seed dispersal in relation to drouth, winter, fire.
8) Interdependencies including food chains. Several examples are always evident; after pointing one out and questioning the group, they become aware of others and share in the discussion.
9) Comparing prairie with adjacent plant communities; the oak forest and pine plantation.
10) Plant succession - examples near the open-grown "Jackson Oak" and an old fence row, and the oak openings created in these places by burning-are meat for much discussion.
11) The values of prairie, including study, research, beauty, roadside, wildlife.

Activities, especially seed collection and cleaning, mostly by boy and girl scouts, 4H clubs and other volunteer groups, has been an especially successful approach to learning as well as providing seed sources for plantings, research and seed exchange. After a brief explanation of why seeds are valuable and needed, the youth are asked to collect certain species. They become aware of distinctive plant species and become very interested in the total plant, seed structure, and that plant's importance in prairie composition. Many groups come back annually, requesting to help, their advisors commenting that this activity ranks highest in meaningful service projects. Hopefully school classes may be brought into the seed collecting program with followups like growing seeds in the classroom, and planting a school prairie as one Madison school is now doing.

Appended here is a report on Arboretum use in public and youth education reprinted from "Arboretum News", Winter, 1968 (Vol. 17, No. 1).

Arboretum Tours on The Grow

Public interest in the University of Wisconsin Arboretum is growing phenomenally. In the past three years, both public and requested tours have doubled and redoubled, as summarized in Figure 1. Several recent developments have spurred this interest: The Arboretum Movie, Nancy Sachse's book, "A Thousand Ages," the Madison School Forest, and Dr. James Zimmerman's interpretive tours of the Curtis Prairie helped attract visitors with deep interest in the natural world, and led to the expanded tour program now offered. This program comes when national alarm over resource losses and environmental contamination is turning people's attention to the natural ecosystem. At the same time educators are placing greater emphasis on multisensory, direct-approach learning, meaning outdoors. We must add here that experience has led us to decrease labelled trails, and to increase our emphasis on guided tours and away from sole reliance on self-guiding trail booklets like our "Guide to the Arboretum Prairies" (Reich, 1972).

All three of the Arboretum's purposes figure in a guided tour: research, teaching, and restoration of the spirit. Each tour is an adventure; unexpected observations are explored with a "let's find out together" attitude. Guides "field" comments and inquiries expertly, relating them to ecological principles and conservation ethics. Special attention is given to features which indicate research is in progress. Numbered trees, soil plots, quadrats, instruments, and insect traps stimulate curiosity and lead to discussion about what is known of our natural biota and what is not known.

One type of tour is the Sunday afternoon "open house" from 2 to 4 p.m. Newspaper notices and parking lot bulletin boards indicate tour area and anticipated highlights. In 1968, these public tours were held on alternate Sundays from April 7 to October 20 inclusive. Spring groups visit the early wildflowers in Gallistel and Wingra Woods and the junction of Noe Woods and Leopold Pines. Special meetings to observe migrating birds, woodcocks' courtship flights, and frogs are also announced. From early summer through fall, the ever-changing panorama of flowers and grasses in the mosquito-free Curtis and Greene Prairies receives the most attention. Brilliant foliage and animal activity in the forest attract many in the fall. Even the special winter hikes are popular; two recent trailing and tracking tours drew 190 enthusiastic explorers, including a number of alert children who discovered many animal signs despite lack of snow.

More than 70% of Arboretum tour groups are school children, supplementing classroom curriculum with direct experience in the field. Here students may become personally involved in discovering interesting facets of their natural enviornment. Beginning concepts of plant communities, natural resources, and the interdependence of all living things are introduced; but the guides' major role is to encourage a sense of awareness - to plant seeds that may motivate deeper interests later.

Many field trips center around particular study units. Arboretum springs and wetlands were observed by 1,600 Dane County students last fall as they studied water resources. Attention was drawn to water source, watersheds, conservation and pollution. Plant and animal adaptations and dependence upon wet habitats were explored.

In addition to Sunday public tours and elementary school classes, many other groups schedule tours with a guide. Classes come at all seasons from our campus and from private and public high schools and colleges in southern Wisconsin and northern Illinois. Teachers, civic and church organizations, garden clubs, golden age groups, 4-H clubs, and Boy and Girl Scout troops are accommodated. Sometimes a guide has three types of tours to cope with in the course of a single day.

The guides are the essential factor in this successful tour program. At present we have 15 well-trained naturalists on call, mostly recruited from Dr. Zimmerman's "Reading the Landscape" class at Madison's Area 4 Technical College. Most of them are homemakers or graduate students, coming with varied skills and background interests as well as experience in group leadership. They must be available on short notice for the intensive tour schedule of spring and fall seasons.

Enthusiasm and ability to share the wonder of each discovery are important guide qualities. Sharing and learning goes on year round as guides get together regularly for study sessions both indoors and out when ideas and techniques are exchanged. Before each tour, the guides schedule a dry-run hike to anticipate features deserving attention and interpretation. In addition to continual encouragement by Dr. Zimmerman and former Arboretum Director Dr. David Archbald, the guides have the benefit of training sessions with experts who generously donate their time. This winter, Professors Eberhard Wahl, Robert Ellarson, Francis Hole, Robert McCabe, Robert Dicke and Joseph Hickey explained their research and shared their expertise. Mrs. John Thomson, who gave guides a moss study course last year, is currently offering a fern-identification class.

As public interest in the Arboretum mounts, understanding of measures necessary to maintain ecologically sound plant-animal communities grows. Inquiries regarding "when the prairie will burn" vie with "when the lilacs will bloom." Capitalizing upon public interest, guides gain an excellent opportunity to inform and interpret Arboretum purposes while encouraging proper use. The basic philosophy underlying the tour program is that the best insurance for securing and maintaining Arboretum goals is an educated and concerned public.

Testimony to the soundness of this view is the fact that despite recent increased public visitation, vandalism and littering have actually declined. Public responsibility was much in evidence this past fall. On several occasions children, adults, and motorists in the Arboretum mistook our "planting" activity for "removing." It was rewarding to have passersby care enough to stop and indignantly point out, "You can't dig up plants in the Arboretum!"

Contacts made in connection with tours have brought other rewards. Girl Scout, Boy Scout, Madison Youth Council, church and University student groups have volunteered many hours of service. Their continuing projects include litter pickup, honeysuckle and buckthorn removal, seed collecting, trail maintenance, and erosion control. Individuals have volunteered seedling transplanting, secretarial work, and mounting of plant specimens.

The desirability of informing the public of Arboretum goals and purposes, interpreting the Arboretum's landscape, and encouraging proper land use has long been recognized by the Arboretum Committee. The Friends of the Arboretum, in their role of supporting educational projects, financed a part-time tour coordinator and guides in 1966 to satisfy increased tour demands. Dane County, recognizing the direct value of the Arboretum to its educational and extension activities, has hired Mrs. Walter Fleming to continue coordinating tours and conservation and extension activities. Thus both Arboretum and county parks benefit. The Friends of the Arboretum continue to finance the tour guides on Arboretum property and occasionally other sites.

The encouraging progress of the Arboretum tours demonstrates again the public's growing concern for the natural environment and their appreciation of the values of the Arboretum.

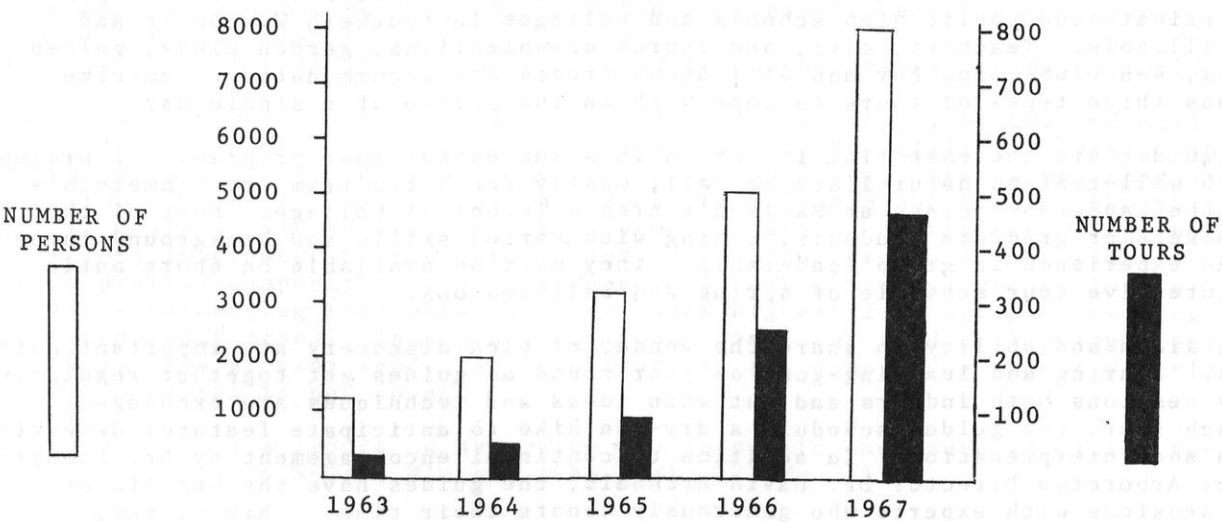

FIGURE I

SMALL SHOW PRAIRIE EXTENDS EDUCATION

BY

Douglas E. Wade

Outdoor Teacher Education Department
Lorado Taft Field Campus
Northern Illinois University, Oregon, Illinois

ABSTRACT

Remnants of a hill prairie at the Lorado Taft Field Campus were recognized through on-site inspection in 1964 and analysis of photographs taken in 1902. Most of the bluff area on the campus has, since 1902, become treed, but some hillside prairie remained. A small area was weeded and burned over a period of six years, so that it demonstrated prairie aspects. Efforts are made to maintain the "show" aspects so that students and teachers can look at the site, but because of its small size, viewers are asked not to enter the plot. An old white oak adjacent demonstrates the aspect of oak openings, and comparison of open-grown with forest-grown trees. Most viewers were previously almost totally without real concepts of what midwest prairies were like.

Introduction

Situated on a dolomitic limestone bluff overlooking the Rock River in the northern part of Illinois near the town of Oregon, and 35 miles west of the main campus of Northern Illinois University at DeKalb, lies the 147 acre Lorado Taft Field Campus -- home center for the Outdoor Teacher Education Department (OTE) in the College of Education.

Each year during the fall and spring semesters, OTE with a teaching staff of eleven engages some 2,545 elementary junior and senior majors in resident programs at the Taft Campus. OTE currently has over 100 graduate majors and offers in summer sessions OTE courses to these and in-service teachers. In total, about 5,200 persons, related to teacher-training, use Taft facilities annually. This count includes elementary and middle school students and their teachers who attend one-week resident sessions supervised and taught by elementary education seniors; secondary education majors, who come largely for one day in the field; and conferees, visitors, and educators in general from many states and countries. The primary impact area for OTE in Northern Illinois University covers some 23 northern Illinois counties from Chicago west to the Mississippi River.

Some Historical Evidence of Prairie at Taft Campus

From photographs taken in 1902, one can ascertain that much of the west-facing river bluff at Taft and adjoining Lowden Memorial State Park was "hill prairie." Some descriptions of hill prairies are given by Fell and Fell (1956) and Evers (1955). Betz (1965) places the Taft Prairie in the "high, Dry Prairies" category. Botanical surveys of the bluff from 1954 to 1969 revealed evidence of relict patches and scattered stands of prairie plants. Aerial color slides taken in 1968 furnished more evidence of the extent of prairie remnants.

Several large, open-grown oaks persist (Quercus alba, Q. macrocarpa, Q. muehlenbergii, Q. velutina, and Q. ellipsoidalis). Ring counts made on an open-grown white oak which fell during a fierce wind storm in July 1969, indicate these oaks started 200 to 250 years ago.

By counting rings on a large number of trees and shrubs cut in 1969 on the bluff slope (being cleared for an added acre of restored prairie) one of my students and I determined that woody plants began to invade the open hill prairie in 1906. An unwanted invader, white sweet clover (Melilotus alba), was, I believe, seeded in the 1930's for erosion control in an effort to heal some raw paths traversing the steep slope especially in the vicinity of the famous Black Hawk statue and the Ganeymede's Springs.

Oregon, Illinois, and vicinity was settled in 1836. Until 1940 Ganeymede's Springs (at the base of the bluff on the Taft Campus) was the site of many picnics and heavy fisherman use. It is quite probable that picnickers' and fishermens' campfires occasionally got out of control and raced up the slope, thus maintaining prairie. Historically there were several prolonged drought periods, especially in the late 1800's (Wade, 1938),and we hope to study cross-sections salvaged from some of the old oaks for correlations with drought years during which fires could have been more prevelant. (These cross-sections will be used in exhibits placed near the show Prairie and in conjunction with one of the large oaks still standing.)

Prairie Restoration Efforts at Taft Campus

Inspired by prairie studies undertaken by workers at the University of Wisconsin, I started in 1964 a restoration at Taft of a quarter-acre patch on the hillside. We later named it "Show Prairie." (It could well have been named "Chigger Prairie" as most students and others who assisted could attest!) In the past seven years, the woody plants and weeds have been removed annually and fire applied three times, with the burning done in the spring when Kentucky blue grass leaves reach a height of one inch. Starting in 1968, we broadcast prairie plant seeds and raised seedlings for transplant in the Show Prairie and contiguous areas.

Some 40 prairie species have been listed for the Show Prairie, with Indian grass (Sorghastrum nutans) and Big Bluestem (Andropogon gerardi) dominating. Two large open-grown oaks beautifully frame the plot.

Some Educational Implications

If this Show Prairie were to be maintained with its plants erect, it could not be entered except carefully, for weeding. Thus, looking in at it from the outside became its primary educational function; a build-up of visually-oriented feelings and hence its name, "Show Prairie." (Summer students do have a chance to walk through several nearby prairies, especially a fine blacksoil mesic prairie four miles south-east of the campus along the Burlington Railroad.)

At the Show Prairie, many students and teachers make a start on perceiving, discussing, and understanding Midwest Prairies. We have noted most of these viewers have few ideas about the true nature of prairies. Those from Chicago and vicinity entertain the concept, "prairies are weedy or vacant lots or fields;" others visualize a "sea of tall grass."

After six years, we do know at Taft Campus that there has been a remarkable rise in the level of teacher and student interest in prairie and prairie-oriented activities ranging over identification, life histories, ecology, management and restoration, literature, research, monitoring, art, photography, history, land ethics (value systems), aesthetics, land planning and zoning. Some of the students and teachers have become active in organizations such as the Illinois Chapter of the Nature Conservancy and attended the first two Prairie Conferences (1968 and 1970).

Fortunately for us at Taft, there are within a 30-mile radius a fair variety of other prairie remnants which we can visit and study. Within five miles lies the NIU-owned 57-acre Pine Rock Nature Preserve with 25 acres of marsh and dry sand prairie. The use of this preserve by Taft and main campus classes and researchers is increasing. (Wade and Wade, 1970). Some 300 Field Science (OTE 415) students have in the past six summers, visited prairie restorations at the Morton Arboretum (Lisle, Ill.) and the University of Wisconsin Arboretum at Madison.

My wife and I have, over the past six years, engaged in a collection of plants at the Pine Rock Nature Preserve. Some duplicates of the collection are housed in herbarie at NIU and the Illinois State Museum in Springfield, with a complete voucher collection in our own private herbarium, which is open to students and researchers. Additionally, for educational uses, I am assembling a set of prairie slides, not only of the Pine Rock area, but other prairies in the Midwest. On our own property, a mile and half southeast of Taft, we are restoring a gravel hillside prairie and many students have used it for study and photography.

Long-range plans for Taft Campus and possibly Pine Rock call for developing additional prairie stands with access paths which will extend the diversity and range of

feelings and understandings, as well as refinements of educational and management techniques.

Exposure in the field provides the initial feelings which can, through some guidance, fan out into a multitude of interconnected interests, activities, and problems. It would seem then that a large and important part of education (really "of living") should consist of some familiarity with a diversity of environments. Outdoor education (whether we dub it nature study, field science, ecology, conservation, resources education, or environmental education) seems to be faced with a considerable challenge in teaching us to want to and how to save a remnant variety of wild nature -- the prairies, the marshes, the woodlands, and the unstraightened and unpolluted streams. At Taft Campus, a tiny patch of restored prairie has given us some clues, procedures, and action.

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PRAIRIE IN EDUCATION

By

David Monk

Educational Resources in Environmental Science
1201 West Springfield, Urbana, Illinois

ABSTRACT

The as yet unfunded and unhoused student-initiated Educational Resources in Environmental Science aims to improve college-level instruction across all fields, especially at the freshman level. ERES has already provided to ever-widening circles the following services as demand has increased: information on natural areas with teaching potential, printed and visual teaching aids to assist instruction, seminars to provide background or discuss principles, arranging of field trips and field training of instructors. Much of the work so far has concerned Brownfield woods, which includes a small prairie, available within 5 miles of the Urbana campus for trips within 2-hour laboratory sessions. Two other prairies - Mayview and Rantoul - are also visited. A growing supply of displays, films, slides, tapes and trail guides are available at cost.

EXIT ORCHIS

By

Aldo Leopold
(1887-1948)

Wisconsin conservation will suffer a defeat when, at the end of this week, 75 cattle will be turned to pasture on the Faville Grove Prairie, long known to botanists as one of the largest and best remnants of unplowed, ungrazed prairie sod left in the State. In it grow the white ladyslipper, the white fringed orchis, and some twenty other prairie wildflowers which origianlly carpeted half of the southern part of the State, but most of which are now rare due to their inability to withstand cow or plow.

Thirty miles away a C.C.C. camp on the University of Wisconsin Arboretum has been busy for four years artifically replanting a prairie in order that botany classes and the public generally may know what a prairie looked like, and what the word "prairie" signifies in Wisconsin history. This synthetic prairie is costing the taxpayer twenty times as much as what it would have cost to buy the natural remnant at Faville Grove, it will be only a quarter as large, the ultimate survival of its transplanted wildflowers and grasses is uncertain, and it will always be synthetic. Yet no one has heard the appeals of the University Arboretum Committee for funds to buy the Faville Grove Prairie, together with other remnants of rare native flora, and set them aside as historical and educational reservations. Our educational system is such that white fringed orchis means as little to the modern citizen of Wisconsin as it means to a cow. Indeed it means less, for the cow at least sees something to eat, whereas the citizen sees only three meaningless words.

In preparation for the hoped-for floral reservation at Faville Grove, the Botany Department and the Department of Wildlife Management of the University have, during the last three years, mapped the location of each surviving colony of rare flowers, and each spring have counted the blooms. It was hoped to measure against these data the response of the flowers to complete future protection. The data will now serve to measure the rate at which destruction by grazing takes place. It is already known that with the possible exception of ladies tresses, all the rarer species succumb to pasturing. That is why they are rare. Few of them succumb to mowing, hence the past use of the Faville Grove Prairie as haymeadow has not greatly injured its flora.

In my opinion no individual blame attaches to the owner of the Faville Grove Prairie for converting it to pasture. The public taxes him on the land. It is not his obligation to provide the public with free botanical reservations, especially when all public institutions, from the public school to the federal land bank, urge him to squeeze every possible penny out of every possible acre. No public institution ever told him, or any other farmer, that natural resources not convertible into cash have any value to it or to him. The white-fringed orchis is as irrelevant to the cultural and economic system into which he was born as the Taj Mahal or the Mona Lisa.

John Muir, who grew up amid the prairie flowers in Columbia County, foresaw their impending disappearance from the Wisconsin landscape. In about 1865 he offered to buy from his brother a small part of the meadow of the family homestead, to be fenced and set aside as a floral sanctuary or reservation. His offer was refused. I imagine that his brother feared not so much the loss of a few square rods of pasture as he feared the ridicule of his neighbors.

By 1965, when the rarer prairie flowers are gone, the cultural descendants of John Muir's brother may look at a picture of the legendary white fringed orchis and wish they could see one.

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Note: Aldo Leopold was the founder of the science of Wildlife Management and professor of this subject at the University of Wisconsin in Madison. He is now well known as the author of the fundamental text in this field, as well as the lyrical essays collected in "Sand County Almanac." The above appeal, written May 15, 1940, so simple, yet magnificent in its eloquence and emotional in its urgency, was successful in stimulating purchase of a 40-acre piece of Wisconsin prairie. Spared damage from "cow or plow", this small piece of the Faville Prairie has become one of Wisconsin's finest scientific areas. Today, administered through the University of Wisconsin Arboretum, it is useful in research, indispensible in teaching, and unsurpassed for its beauty and biological interest. Leopold was one of the early inspirers and guiding lights of the Arboretum whose own difficult beginnings are documented by Nancy Sachse, 1966 "A thousand Ages."

CHIWAUKEE PRAIRIE - PAST AND PRESENT

By

Phil Sander

8026 7th Ave., Kenosha, Wisconsin

Searching my memory for the first time I saw and walked the Chiwaukee Prairie, I find that it was more than fifty-two years ago. The land then was a true wet prairie with no roads, no trails, no drainage ditches, and no homes. The only easy access was to walk in from either the Chicago Northwestern Railroad tracks or the Lake Michigan beach.

In those early days this Lake Shore area, of approximately 350 acres, was called the Whey Prairie. The wet undulating depressions attracted many migrating ducks and shore birds. On several occasions I observed a group of Sandhill Cranes, and in late September, watched for the Hawk migration gliding over this well-defined prairie flyway.

Early in October, I hunted the Prairie and Lake Michigan shoreline for Blue Winge Teal, and the elusive Jack Snipe. Several times I had good luck bagging a Canada goose or Brant. The Prairie remained wet most of the year and few people ventured into this wild and treeless tract. A team of horses were occasionally pastured in the prairie, but to my knowledge, it has never been disturbed by the plow.

The abundance and variety of plants flowering through most of the growing season made this a spot of spectacular beauty. Plant communities, such as the Shooting Star, Indian Paint Brush, Liatris, White Fringed Orchid, Gentian and other plant life fascinated me. I often told others about the prairie - only to be answered that flowers and prairies were common, especially in a township named Pleasant Prairie.

During the "Thirtys" a change came to the land area. Krenn and Dato Developers, agents for Mrs. Edith McCormick, purchased the land and surrounding farms to build a model city called "Edithon Beach." Another group plotted the area south to the Wisconsin-Illinois state line. They named it "Chiwaukee." Roads, lots and a golf course were layed out. Ditches were dug for drainage to make the land saleable. Land sales went like wildfire, and salesmen sold lots as a future investment or home site. Soon a number of fine summer homes were built along the Lake Michigan shore and Chiwaukee Golf Club became popular.

During the depression years, real estate dwindled and the project failed. Nature healed its wounds and later, in 1943, the State Planning Commission recommended this area as a State Park. Lack of funds and interest caused the project to be abandoned. Later, land promoters again developed the land north of Tobin Road and started a new series of subdivisions called Carol Beach.

Through the years, I continued my walks to the prairie. Some led to new discoveries in the field of Botany, Archaeology, Geology, Ornithology and several other sciences, each a link in the chain of knowledge which I have enjoyed and shared with others. There are still many new discoveries to be made on this - one of few remainin natural jewels of Wisconsin and best remaining example of a Lake Michigan shore wet-mesic prairie.

My walks led me to discover an archaeological feature on the top of the ledge adjacent to the prairie. It was an early Indian occupation site. Each spring in the plowed fields, rain and wind would expose surface artifacts of the Woodland and Upper Mississippi culture. Arrowheads, spears, scrapers and an axe were added to my collection.

The top of the ledge was the location of the old sand ridge trail. Evidence of flakes of chert and broken fire rocks point to the camp site of these ancient people. Stone to make their implements were probably picked up at the lake shore. They used the prairie as hunting grounds as shown by hunting arrows, spears and large scrapers. No pottery has been found. The Indian people gathered the plants of the prairie for food, like the wild onion bulb, cattail tubers, etc. Plants were gathered for medicina

purposes; grasses for baskets; cattail leaves for mats and the Gentian root for tea. My prize surface find was a paleo fluted point indicating the ancient hunters and gatherers traveled the west shore of Lake Michigan soon after the northern glacial ice retreated. An estimated time table may be about 5,000 B.C.

In the late fall or early spring, a keen observer can see parts of the prairie that were formed in Pleistocene times. An interesting geological feature bounds the west border of the prairie. Geologists have determined that the area inland for several miles, including the Chiwaukee Prairie, was impounded by glacial Lake Chicago. Some of the stages are still visible.

The highest stage is known as the Glenwood stage or 55 Foot Beach. The second is the Calumet stage or 38 Foot Beach, and the third is the Toleston stage or 23 Foot Beach. This stage can be seen as the ledge west of the Chiwaukee Prairie. At the state line west of the tracks is a wave-cut bank of the Toleston Terrace.

North of the 1/2 mile section road is the abandoned Toleston Beach. In places, the sand is visible as soils have not built up as in the low prairie. Measuring the humus soil that has built up from decaying plant vegetation, I have found it to be approximately 15" to the sterile beach sand.

Sighting eastward from the higher west terrace, one can see many low undulating ridges, running parallel to the lake. These ridges could be the storm beaches formed by wave action as the lake receded. The ridges vary in height from one to two feet.

Another very interesting feature was discovered on the lake shore opposite the prairie and about 200 feet south of Tobin Road. In April of 1969, violent north-eastern storms on Lake Michigan caused wave erosion to draw the sand from the beach which uncovered an old peat bed. The peat extends approximately 100 feet parallel with the shore. The bed with visible layers of marl and hematite extends above the water approximately 18", and from the shore extends into the water about 15 to 18 feet. Samples were obtained for future pollen studies. Also, a 3" layer of magnetic material was visible in the sand bank and scattered on the beach. Roots and tree stumps were exposed. A sample of the wood was sent to Forest Products Laboratory, Madison, Wisconsin. Correspondence with R.C. Koeppen, Botanist of wood identification research, has identified the wood as eastern white pine (Pinus strobus) evidently, remains of the post-glacial forest. There is still a relic stand of white pine in the northeastern corner of Illinois at Illinois Dune Park, near Zion. The range maps do not indicate it extends into Wisconsin. Samples of the wood are prepared for Carbon 14 tests.

In 1965, promoters planned a large Marina located at the southeast edge of the prairie. Conservationists,fearing that the project would affect the drainage and spoil the ecology of the prairie immediately called a meeting. A group spearheaded by Al Krampert organized the Nature Conservancy Committee of Kenosha and Racine. Through solicitations, gifts and money-raising projects, the organization has now acquired 78 acres of prime prairie lands. The stewardship of the prairie has now been turned over to University of Wisconsin - Parkside. Additional land will be added as it becomes available and price-realistic.

Future generations are charged with using the Chiwaukee Prairie wisely, to make new discoveries and research this natural area to gain a better appreciation of our native Wisconsin heritage.

THE CHIWAUKEE STORY

By

Alfred P. Krampert

7754 7th Ave., Kenosha, Wisconsin

In May 1965, Phil Sander and I stood in the gathering dusk on the Chicago Northwestern right-of-way overlooking Chiwaukee Prairie struggling with our consciences trying to arrive at an important decision. I was seeking his support and I strongly suspect he was seeking mine to move in the direction we knew we should move, the decision to save Chiwaukee Prairie.

All day long, we had tramped over the prairie,pouring over platted maps, checking out who owned what, trying to estimate how long, how much the owners had paid for their parcels, what the possibilities were of getting the numerous owners to dispose of their land, wondering why they had bought it, why they hung on to it, what they wanted to do with it, and most of all - wondering how it was possible that this virgin prairie could have survived in a growing Metropolitan area in the hands of so many owners. It was a miracle that it was still there. Perhaps another miracle might save it. All of these things were running through our thoughts.

The number of owners involved was the greatest obstacle. They were literally scattered all over the four corners of the earth. The Wisconsin Department of Natural Resources, four years earlier had turned down the acquisition of the Prairie for this very reason. The high cost of land in a Metropolitan area, especially along Lake Michigan,was another problem. No attempt had ever been made by a local group to solicit funds from the public in Kenosha and Racine to preserve a natural area. How would the public respond? How could you convince people to donate money to preserve what they considered a bunch of noxious weeds?

Several months previous, the Wisconsin Chapter of the Nature Conservancy had voted to back our Committee for an initial purchase, but there were a few on the Board who had serious doubts about the project's successful conclusion, and they were right - because a great deal of luck would have to be with the Committee. Anyone in his right mind could see that you would have to have everything going your way if you were going to succeed.

Thirty-five years earlier, as a 12-year-old farm boy going to a two-room country school, I used to sneak back into the library which was nothing more than a cubby hole stuck off from the main classroom, but it had a lot of good books. In addition to the books by Altsheller and Zane Grey, it had several by Hamlin Garland. I became so fascinated with his beautiful descriptive writings , such as Boy Life on The Prairie and Son of The Middle Border,that I entirely neglected to do my school work and I still recall a Physiology quiz in which the teacher asked me, "Alfred, how many openings are there to the alimentary canal?" I hesitatingly blurted out, "one". She said, "Alfred, if you only had one opening to your alimentary canal you would die; there have to be two". Everyone laughed, much to my embarassment.

About the same time that I became so engrossed with Hamlin Garland, Edith Rockefeller McCormick's dream of Edithon Beach along the shores of Lake Michigan just north of the Illinois State line came tumbling down along with the stocks of the major and not so major corporations in the country. Thus the Chiwaukee Prairie received a new lease on life for the time being at least.

Much had happened to me between '30 and May of '65. I became a salesman intrigued with motivating people to do what they should do, but Garland, Altsheller and Grey had done their job well; they had left a lasting impression on the mind of a young boy, and he never lost his love for nature and the "great out-of-doors".

After our marriage, my wife and I made numerous trips to the West which brought us in contact with acres of wild flowers in the high meadow country. We became enthused with the study of wild flowers; if only we could have this close to home, but the Virgin Prairie was gone. Garland had stated this in his writings. He looked for it in his latter years, but it was gone.

You can imagine our surprise when on Memorial Day, 1961, while travelling south on Lake Shore Drive in Kenosha County and turning the corner onto Tobin Road, we saw millions of Shooting Stars, Orange Pucoon, Yellow Eye Grass, Lousewort and Bird Foot Violets stretching toward the horizon as far as the eye could see. We got out of the car and walked through the fields. "Karla", I exclaimed, "this has to be Virgin Prairie." I didn't think any of this existed anymore. Thirty-one years after I read Hamlin Garland, I experienced what he had written about. You might laugh at this, but I became so excited about the prairie that I went to the library and dug out all of his books and read them over again.

So there we were, in May, 1965; Phil Sander and I standing on the railroad track, overlooking this gorgeous hunk of prairie, unsure of ourselves; then we recalled the meeting that took place in the Kenosha County Court House three months earlier. It was a regular County Board meeting, and the County Board was to vote on whether to rezone part of Chiwaukee Prairie from residential and agricultural to commercial so that a Corporation, Pompei on The Lake, could dredge a channel and basin and develop Chiwaukee Prairie into a huge Marina. Letters pro and con had appeared in the local paper's Voice of The People column on the proposed rezoning.

It snowed hard the day of the meeting and toward evening the wind began to blow and drifts began to appear in the streets. I didn't even know if I could drive the 2 1/2 miles from my home to the Court House. When I got there, the room was packed with people, most of whom I didn't know. Dr. Darnell from Marquette University spoke against the rezoning. Mr. Krueshke, from the Milwaukee Museum,and Kenneth Dearolf from the Kenosha Museum spoke in opposition. Long after the meeting started, in came Dr. Orie Loucks and Dr. Hugh Iltis, who had driven in a blinding snowstorm all the way from Madison to speak out against the proposed Marina. "Gosh", I thought to myself, these are really dedicated men to drive all the way from Madison and poor me worrying about only 2 1/2 miles.

There was Louise Erickson, Dr. Von Jarchow and Dorothea Kuehnl, who had brought down a group from Racine, a drive of more than 10 miles.

I'll never forget Hugh Iltis standing there looking like a skinny Santa Claus with a black beard covered with half-melted snow pleading with the County Board not to rezone in these words, "You are rezoning land in Pleasant Prairie Township. Your children will ask, 'What is a pleasant prairie?', and you will have no answer - for you will have destroyed it." I got my two bits worth in by telling the board, "We would be as bad as the book burners and would have to account for it some day."

It didn't do any good. Our present Judge Morton, representing the Marina, talked glowingly of how the new Marina would spend 12 million dollars, perhaps even 20 million. John Estabrook, who owned a considerable tract of land in the area, and would profit greatly, talked about building houses and adding to the tax base. The dollar sign carried the day and things looked very dark, indeed, for the Conservationists.

A meeting was hastily called in the corridor of the Court House. Louise Erickson managed to get a pad and had everyone write down their name, address and telephone number. Dr. James Olson, from the University of Wisconsin, Kenosha Center, said we could hold meetings in his laboratory. Hugh Iltis stuck a big fat file on Chiwaukee Prairie in my hands and said, "Here, it's up to you people locally to save that prairie."

We met several weeks later at the University Center, formed our Committee and voted to ask the Nature Conservancy to help us. We attended a Board Meeting of the Wisconsin Chapter of the Nature Conservancy in March, presented our case,and Paul Olson, Chairman of the Wisconsin Chapter,was willing to gamble with us. Our committee was an unknown quantity, but he thought the gamble should be made and he convinced the Board. Our committee had proposed the acquisition of a mile long strip in the prairie, 100' wide, which broadened out to 300' at one point. It was an odd shaped piece that was intended, at one time, to serve as an electric line right-of-way with a passenger station at the midway point of the mile strip. We thought we could get it for $5,500 and then try to make additions to the strip. If we failed to raise the money, the Wisconsin Chapter would be out the money and would own a 100' wide strip of prairie, one mile long, and there were lots of 100' railroad rights-of-way in the state.

All of these things ran through our minds as Phil and I stood there. The offer to purchase had been prepared and the check for earnest money had been drawn. The members of our committee had told us they would back us to the hilt. They would work hard to raise the funds. They would help on publicity to get the public interested, but Phil and I knew that more than the initial purchase was involved. We needed more than the 100' strip and there was no way of even knowing whether we would ever acquire any more. It was an awful hard decision to make.

It had been a beautiful day. The Shooting Stars were at their best. All day long we would search the sky for the Upland Plover to watch it plunge toward earth in its steep dive and thrilled as we heard the winnowing of air through its wings. We heard the incessant chatter of the Bobolinks and the trill of the Marsh Wren. There was more to this than saving the White Fringed Prairie Orchid. Finally, Phil turned to me and said, "Al, we've got to start somewhere and the only way we'll ever know if it can be done is by trying". I thought of all the people I had met in the past 3 1/2 months who loved that prairie as much as I did. I recognized their sincerity and hopes that it could be saved. "Phil," I said, "The only real thing we've got going for us from a business point of view, is that we've got a darn good committee; without it, we can't accomplish a thing. We'll take one step at a time and perhaps with luck we can put the thing together."

That evening was the turning point for Chiwaukee Prairie. I would be taking too much of your time to tell you the entire Chiwaukee story. Its final chapter may not be written, perhaps for 15 or 20 years from now. The 100' strip has proved to be the most strategic purchase we made. Events may prove that purchase to be the death knell of the Marina, because it appears the Marina didn't even know the 100' strip existed in the southern half of the prairie. The platt books don't show it and that initial purchase put our foot into the entire prairie.

The initial purchase of 15 acres has now grown to 83 acres which is, in itself, a beautiful self-sustaining unit. The Marina owns another 43 acres, which we want, and if we ever get that, we are certain to get the entire 200 acres of the Prairie. Our purchases to date, have involved 62 separate parcels of land at a cost of over $50,000. While this amount of money may seem paltry compared to the cost of Goose Lake Prairie, we have to realize that with the exception of $18,500 which was furnished by HUD, all of the remainder came as donations from individual people and every penny was used for land purchase.

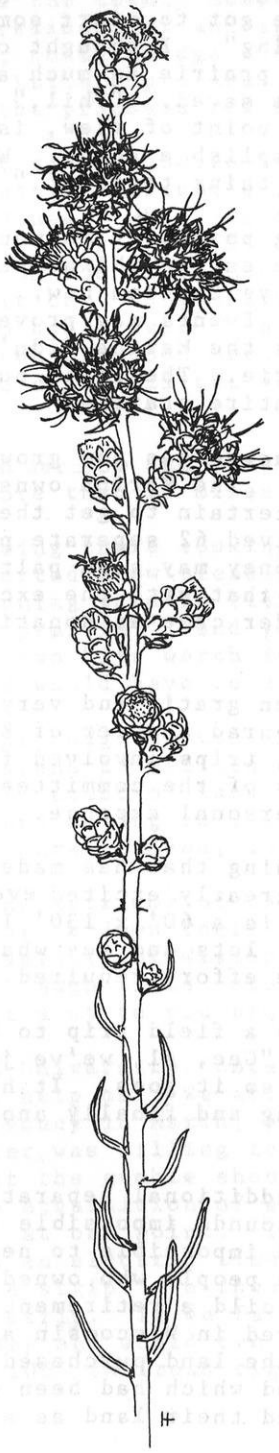
All legal work has been given gratis and very willingly by William Sieker of Madison and Duane Shauffer and Conrad Shearer of Kenosha. Any incidental expenses such as postage, telephone calls, trips involved for land acquisition, have been cheerfully borne by individual members of the committee. Even signs to help protect the prairie have been furnished at personal expense.

However, this is the very thing that has made the Chiwaukee story possible. It is dedicated people, who become greatly excited every time a new addition is made to Chiwaukee Prairie even though it is a 60' x 130' lot or only 1/6 of an acre. Every time you look at those 60' x 130' lots and see what's on it, you become convinced all over again that regardless of the effort required to save it, it is worth it.

Every time our committee has a field trip to Chiwaukee Prairie, it's the same old story. The members exclaim, "Gee, Al, we've just got to save this piece over here, and that over there." And so it goes. It has gotten to be a game - patiently waiting, anticipating, negotiating and finally another piece of the puzzle falls into place.

There are still around 250 additional separate parcels that sould be acquired to round out the 200 acres. It sounds impossible to acquire this by negotiation. Looking back, it also would sound impossible to negotiate for 62 separate parcels, but it has been done. All of the people who owned the land in Chiwaukee Prairie purchased it for speculation or to build a retirement home someday. Of all the purchases made to date, only two owners lived in Wisconsin and both of these lived over 200 miles from the Prairie. All of the land purchased to date has been at a loss to the sellers with the exception of land which had been owned by the Henry George School of Social Science. They had acquired their land as a gift.

A whole book could be written about the hopes and dreams of all the people who owned and still own land in Chiwaukee Prairie. That is what makes the Chiwaukee story so fascinating and exciting. It isn't a one shot deal where you make your deal and it's all over. There are hundreds of people involved, and incredible as it may sound to you, I think it will be a sad day for the committee for Preservation of Chiwaukee Prairie when the day comes that the game will end (see Map Section for Location in Wisconsin.)



THE STORY OF GOOSE LAKE PRAIRIE

By

William L. Rutherford

4801 Prospect Road, Peoria Heights, Illinois

I am very happy to have the chance to discuss Goose Lake with you who understand the zoology and botany and the importance in many aspects of what prairies and the preservation of some of our natural beauty means. I'll defer to Bob and Sibyl Prager here for knowledge of its botany, and tell you how a country lawyer faced the problem of how to acquire what I think is a magnificent heritage for our people in Illinois. It meant countering the bureaucracy and the other form of pollution we haven't talked enough about--the political pollution that is so profound in my home state of Illinois.

The time is so late that I implore you who understand the need to preserve our national heritage to become salesmen, like our very effective first speaker, who move in and get the job done while those who find excuses not to go ahead are still asleep. I'll show you a short movie we tailored to the short attention span of the TV shorts so that it could be used on the people who do not share our interest. We too often talk only to our friends and lose the fight because the vast reservoir of indifference continues to exist and increase.

Let's find the area that I'm sure an effective salesman always has to, and that we have to in the practice of law. What is the point in the juror's mind that will stand the test of his analysis and relate to his life and his interests? I had a chance to try this out at Goose Lake Prairie because I went to Springfield with the belief, one I still feel very keenly, that the most practical thing in the world is idealism. It's the only place you're bullet-proof; here the result of your efforts is really worth it. The narrow view of economic standards we felt were good do still have validity, but are not complete. The people I have met are very hungry for something they can trust and believe in. I often quote from a businessman's journal, the Royal Bank of Canada Newsletter, "there must be recognized the existence of a compact between the dead, the living, and the unborn - that we must not leave the unborn sitting beside debts and depleted natural resources." This is one of those glimmerings that we seek so much. I feel there is a great hunger for a government that recognizes the fragile and very valuable and humbling requirements of stewardship of the trust of one's neighbors to do something decent, not for just ourselves, but for those that will follow us, a true kind of patriotism in operation.

Now, Goose Lake Prairie gave me a chance to have some fun when there wasn't much fun available in Springfield because of the absolute freeze upon money and, worse, upon employment of people who are competent, because of the requirement that we keep many who are of political acceptance whether they did anything worthwhile for the taxpayer or not. Luckily, it had become a campaign issue between both the Republicans and Democrats that Goose Lake Prairie should be preserved.

They envisioned an area of about 1,400 acres located 60 miles southwest of Chicago in Grundy County, just about 1/2 mile south of the Illinois River, within 1/2 mile of the great Commonwealth-Edison Dresden nuclear power plant that has its own problems as you know. The E.G. and E. Railroad, a branch of the U.S. Steel Company, has a bridge across the river, to serve the Commonwealth-Edison Plant. It has a railroad through Goose Lake Prairie to the south, serving the Green Refractories Company that's mining like mad to get the clay to build firebricks and wants all the rest of the clay underlying part of the prairie. Curiously, while many people in Chicago and other parts of the State knew much about Goose Lake, our newspaper in Peoria hadn't chosen to mention it much, and I was embarrassed at the extent of my ignorance on Goose Lake Prairie when I took office.

My very first day in office, I was beseiged with reporters: "Are we going to buy Goose Lake Prairie or not?" The conservationists wanted it; people like Bill Beecher, the very esteemed head of the Chicago Academy of Science, and Jeffrey Short, the head of the Open Lands Project, and other magnificent people had worked their hearts out to try to convince my predecessor to buy it. He had ducked the issue by saying it required too much money. Since the seesaw on price going up between industry and conservation had gotten beyond the financial capabilities of the State,

he said, "let the Legislature decide if you want it or not. Stay away from it, it's a bucket of worms!" On the day we had our conversation before he left and I took office, the only money available was some left over in the Illinois Building Authority. Since our own Constitution prevents bond issues without referenda, created authorities sell bonds, and the state rents the ground over a period of years so that future generations can pay our expenses. Each year, the Legislature appropriates a bit and eventually the state owns it. It is a complete sham.

In any event, the Building Authority, under the direction of a magnificent man named Franklin Schmick, had agreed to pay as much as $1,000 per acre to buy about 1,400 acres of what was considered necessary for the Goose Lake Prairie to have the complete ecosystem that was desired. But, of course, industry jacked the price up to above that in a hurry, and the offers were up to $1,500 an acre, so the approach was, we had no further money, and the Building Authority couldn't buy over-appraisals. (The Building Authority was very skeptical of the Department of Conservation because they had found examples where the Department was trying to get land at $125,000 which they found was worth $35,000.)

It appeared to be an impasse. There were several owners of Goose Lake. The largest portion (about 1,700 acres) had been owned by a family named Collins for over 100 years. They were a little indignant because they had read in the Chicago Tribune about the debates about their land but nobody had even talked to them about it. The other owner, reportedly a tough character, was a contractor named O'Brien who owned the land that his father and grandfather had owned before him. (His grandfather had had the pleasure of a trial for manslaughter, having taken appropriate action against a trespasser; he got a hung jury and got off). The industries' great pressure upon the Legislature and the Governor's Office, urging, at least, that they let conservationists have only part and let industry have part of Goose Lake Prairie, compounded the problem for me.

George Fell had done the magnificent work of preparing maps and studies. He knew how much of the prairie had never been farmed, how much had been plowed a little bit during World War II. He acquainted me with the whole story and supplied me with a map with overlays that was one of the finest sales tools I have ever had the pleasure of using.

At the first meeting of the advisory board of the Department of Conservation, the reporters and cameras were there. "What are you going to do about it?" I said, "First, I'm going to do the unusual thing and try to find out what I'm talking about. Then, I'll answer your questions. And please lay off." I made an appointment with the Collins family, met them right straight out and said, because they were quite indignant with the State, "I'm sorry. I too would be indignant if I had had to read about my property in somebody's newspaper and never had the courtesy of an inquiry. I am here this Saturday afternoon because I'm new in this. I can only apologize for previous bad manners. I'm very grateful that your family has cared enough about this ground to keep it inviolate for future generations. Long after you and I are forgotten, it can have validity, tremendous import for research, education, and really wholesome fun. The most realistic definition I know of the word fun (or pleasure) is watching a child learn something useful, and this would certainly qualify for that. How can be find an answer?"

During the course of the afternoon with their two very competent and very decent lawyers present from Morris, I'd go in the kitchen and talk to them, and they'd talk to their people, and they finally said, "Well, they'd had better offers, but for this purpose, they would take $1,400 an acre, but they wanted to have some action rather fast." I said, "Fine, I'll be back next Saturday." $1,400 an acre! Mr. Scmick had told me they would live with $1,000 an acre. There was no other money available. I knew full well from the information I had had, because I too had gone up for a few evenings to talk to some lawyers I knew, that the State of Illinois, before a jury on dondemnation, wouldn't have a prayer of getting this for less than $1,500 an acre when industry had offered that. I knew that some of the land close by had sold for $6,000 an acre. I had some recent experience near Peoria acquiring a little over 22,000 acres of land. A few of us, our heels dug in, using the tools and imagination and the best efforts we could, have gone from 2,000 to about 24,000 acres in four counties since 1964. So, I've been down the course, know how to carry my tin cup and keep it handy.

I drew up the documents in my own office, saw The Collins the next Saturday, found they wouldn't go any lower than $1,400 an acre, and convinced myself that the price was fair and sustainable before any jury. On Mr. Schmick's word that the Building Authority would still go to $1,000 an acre, I signed personally to buy the ground, and committed myself that day for $700,000 within 90 days. I had to find this somewhere because I knew Goose Lake would be lost forever if I didn't. As I heard your previous discussions, it did make me shake a little; I wondered where I got the nerve at the time.

I had a talented young landscape architect and very competent artist, Ed Hoag, who has since left along with most of my good people when they found that in these four years politics and misuse could not be gotten out of the Department of Conservation. He drew up a beautiful set of pictures of how we would use Goose Lake Prairie if it was ours. He made a map of Illinois, showing Goose Lake just a couple miles south of Interstate 80 which cuts the State, easily accessible from the vast number of people in Chicago who should have the benefit. It could be our educational center for conservation of the State of Illinois. (See map, Anderson paper).

He pointed out that we could make use of the land that lay to the south that had been stripped before. You and I share the feeling that it is nonsense to buy only the virgin ground and then locate the parking lots, toilets, nature centers, and all the rest on it to destroy what we're trying to preserve. Instead of the 1,400 acres they talked about, I decided it should be closer to 3,000 acres, and I took more land that I knew industry would want very badly. (After all, if they're going to cut me in two, I'll start off asking more. I've negotiated labor contracts too!)

So, we figured out how we'd make use of this very ugly strip mine land at the bottom. We came up with some dandy ideas; we'd have our parking there, we'd use some of the mounds for overview and some of the farmland for our bison, so you could see, not a couple of poor old mangy creatures in a room half this size, all worn out in the mud like you see down there at Ft. Massac in Southern Illinois, but maybe 150 acres where you've got to look, like in East Africa, and the youngster has to wait and carefully look behind the bushes for the wildlife. Maybe sometimes you won't see them, and other days, you will see them out there, giving the feeling that our predecessors had, putting realism into the experience.

We had lots of ideas that were fun. The lake is too acid right now to have fish, but, by George, we could change the chemistry of it. So we would approach from the south, use this worn out strip mine land and get people in the mood so it isn't "What's all this money and these damn weeds about?" They would understand what it really could be--the thrill of education and learning, the fun of seeing what you yourself see when you look at something. We sould first take the people into a nature education building. It would be the interpretive center which people could enjoy if the weather is bad. They could push the button and hear the redbird sing, see the picture, and get all the rest.

The center takes care of all age groups; the grandma could stay with the little children and understand things at that level. It would have the library, the museum section, the theatre section so that we could have lectures and the whole gamut of interpretive understanding so that no age class would be disappointed. You would have a full and valid experience, even if weather or misjudged timing prevented setting a foot in the prairie.

Then, we'd go across one of these little lakes, not by a bridge, but by an old-fashioned river boat that you would pull with hand ropes as you did 100 years ago, so the youngsters would have some fun and some physical exercise to wear them out a bit in the process. With glass bottoms, they could see 50-pound catfish and learn that those weeds down there, those pieces of plant life, have a very important role in the system, to help understand prairies, farms, the whole world.

Next, one could go through the next pile of strip mine inside a big sewer tile designed to look like the entrance to a coal mine. It would serve several purposes: the man with his white miner's uniform and all the rest could tell them about some of the geology inside; it could also be a place to wait out a storm. We'd give it the real feeling, we'd bend the tunnel so you wouldn't see light and lose the illusion; when you had to go down to the center and turn, you had entered a coal mine and left it. You would have all kinds of exhibits there, and that was something else.

Further on, you would go to a place called Jugtown because during the Civil War they actually made jugs there from the clay. And then, we'd have a place with eating facilities--the hamburger, or a buffalo burger if you like, or else we'd have the food that was eaten there 120 years ago when white man first saw it. So, each part of the way would be a new experience--something to think about, something to tell the kids back home, something to tell Mom and Dad tonight.

Then, they'd see how the Indians really lived, not in hogans like the Apaches, and the Navajos, not like the Blackfeet and the Sioux, but like our Indians lived in that area, with reed huts and all the rest. And they'd pass a pioneer's place that would have a windmill and a sow and a few other things, and they could see the very meager things our predecessors lived with as prairie farmers.

Now, those that weren't interested enough or became tired would walk back before they messed up the prairie! Those that were interested would stay on the path, now definitely in a frame of mind to be receptive so that you could point out why some people ate cattail roots and these other things. You could see the plants and their virtues, and their purposes, and the animals that lived in it.

So I took the set of pictures, and made an appointment with a prominent Chicago businessman who said he might be interested. Having met Bill Beecher and Jeff Short, and having gotten further information from them, I called this gentleman and said, "I'm in town a week early and I don't mean to be ill-mannered; but I just wondered if you happened to have a few minutes so I could talk to you now, rather than wait a week. Time is pretty precious." He said, "Sure, come on over." I found he had adjourned a director's meeting of a major corporation to let me come in and make my little sales pitch.

Now with enthusiasm and enough thought and enough facts, brass if you will, I told him what I needed and what I intended to do, what I had to do and why. And he said, "I've never met a lawyer quite like you before. How soon do you need the money?" I said, "Right now." Before I got done, he promised me $300,000 on condition that I must never tell who he was, on pain of nothing less than "burning bamboo under you fingernails. You will not disclose this because I really don't have the time to do this very often." When he committed $300,000 the first go around, that was kind of encouraging.

We went to work and simply presented what our people needed in the State of Illinois, a projection of a new image of concern, citizen participation, and a willingness to break the traditions of misuse and clean that miserable mess up. I raised all but about $30,000 and met the deadline. We got the last bit of money delivered within 12 hours of the expiration of my 90-day contract. Then, we expanded the project and raised another $100,000 to get the extra ground.

Now the fun thing about this, the reason I mention the importance of salesmanship and the tools that give the understanding, was that the people who called me over at the Governor's office were a very irate group. A man named Jim Washburn, representative from Grundy County, came to my office as angry as any man ever has been in my life. He had been embarrassed and humiliated because the industry people that he had talked to were fearful I might get this ground bought and they were not about to have it happen. He had assured them, "Don't worry, we've got plenty of time to talk about it." You see, he wasn't tuned in on the new wavelength. When they told him they found it was an accomplished fact, he was offended and came to see me. I'd never met him before and told him, "I'm sorry as Hell that you're angry about this, but I think you've got the best sales tool to develop Grundy County that's ever happened. If you will just believe me you will not be sorry I've done it; I'll take any penalty that goes with it, but this is an accomplished fact. But I'll make it easy for you. I will promise you that a year from now, you will find this is the finest thing that's happened for your people, and those that object simply do not understand; we haven't had communication. It'll be the greatest asset." He wasn't sold a bit, but he was a gentleman about it.

Another fun thing was that when Mrs. Nixon came to Illinois, for the first meeting of the Environmental Council in the State of Illinois that ever happened, at the Field Museum, the E.G. and E. Railroad, whose business manager and sales people had led the fight, were the ones that supplied the private railroad car to bring Mrs. Nixon to see Goose Lake Prairie which she described in their presence as Illinois' greatest natural attractions. That even made the San Francisco paper!

Now handling those people with the E.G. and E. Railroad was fairly simple. They said lots of nasty things about me, and I met them right on their own grounds. I went to Grundy County and talked to the Board of Commissioners. I took the helicopter along, and said, "Please, let me show you. Let's take a free ride." We spent the morning taking a helicopter ride and selling. No anger. I said, "Look, this is not a case of anger. These are things I have to do, but I think you'll approve if I could only find the words by which you can understand what we're after." Then I wrote a letter to the President of the E.G. and E. Railroad, a fellow by the name of Fred Oakey, and I said, "If you've had enough committees and small boys working on this thing, why don't I buy you a hamburger and let's make a decision." He was a good sport. He came out to the Morris Airport and we did that, only he bought the hamburger. And, you know, he was the man who, when he understood it, not only arranged the train ride for Mrs. Nixon, but was good enough to send me a book on his interest in geology, and then he set up a meeting at his country club in Pittsburgh so that I could meet the President of the Green Refractories.

These were the people who really were after the ground, Green Refractories and Righto Chemical who had threatened to pull out $125,000,000 of improvement that Illinois needed for industry and taxes and all the other traditional reasons unless we agreed not to have a park there. It was fun. I met these two men, and Green Refractories will go out of business in a couple of years if they don't get the clay. Well, while they were threatening to sue me and all the rest, I knew it took about so long to prepare a complaint, about so long for the lawyer to get around to doing it; so I called upon Mr. O'Brien one evening. He said, "I've been looking for you." I said, "Yes, and thank God you and your family have cared enough to take care of the ground, and I'm here to see if you can't help me, too, like the Collins family has. I had to get one at a time; I picked them first because their ground is many more acres." "How much you going to pay me?" I said, "We'll pay you exactly what we paid the others, but I can't pay you more." "You're not going to chisel me down? Some people say my ground is worthless." I said, "I don't think so. I don't think it would be fair, I think you have a great economic potential. I'm not going to kid you that I think your ground is not worth more. But I can't pay more. Will you go along?" "Oh," he said, "Hell, go see my lawyer across the street." This is the way that piece was bought.

Candor, directness and speed are vital; when the person is in the mood, don't waste a minute. To go back to Fred Oakey...We sat in the back of his car as we drove into town, because I had been to a meeting in Washington talking to these two people about our mutual problems. They had exercised an option on 60 acres of ground just south of the O'Brien property, a small portion of which had been a lake, the virgin ground, the rest of which had been farm but had the great clay deposits. "Are you going to condemn us, are you going to litigate?" I said, "No, I've got a better idea than that. On that piece of ground that you have in mind, if you'll promise not to distrub the lake (only 3 or 4 acres), you can put in this impervious clay so that it will not drain our ground. You can do it in such a way that when you're done, it will make a natural-looking lake. We can use the great water supply for our wildlife and all the rest. It's better than a cornfield. If you'll move your easment access to the other end so it won't bother our interpretive center or cut across the area we'll use for our teaching, if you'll give it to the state, you can get some good tax deductions. You can still mine out the things you want to. You can have what you want, I can have what I need. It'll save the taxpayers $100,000. It'll save you a law suit. It'll save you my having to take the whole works." It was six minutes by my watch by the time he said, "That sounds like a good idea. We'll do it." We solved the problem with industry and the owners, head on, fair, tough, but informed!

But this isn't the whole story of Goose Lake Prairie. The Field Museum had agreed to take over the concession of conservation and education. It needed an outdoor laboratory. It's a natural. They have the kind of expertise, the kind of quality, that Illinois needs so desparately to be free of the patronage, the political nonsense. It would be above reproach; nobody could outbid them in terms of quality. It would serve their purpose and our purpose. They would set up, they would even design the interpretive center. Before I was promoted from director of the Department of Conservation to the super-Cabinet position of Coordinator of Environmental Quality from which I happily, or reluctantly, left when I found out what it really was, we had set it up that they would do this job. We had the

contracts, the design ready to have Goose Lake Prairie as the center of conservation education for the State of Illinois. It would have been operating as of this spring. We could have had the parking lot, the toilet, the views, the fencing, the bison. We could have had enough for people to really see, and would have been well on our way for the interpretive center and these other things. I had people that had promised me substantial sums of money to help me build these things; they wouldn't be tax dollars.

There's where the fairy story ends because now it's back in politics. The prairie is bought--not just the 1,400 acres but a great deal more--thank God that's done. But the mission isn't completed. Now the only good thing about the lethargy that exists among these people is that two years can go fairly fast and they probably won't get around to doing very much that's too damaging. The prairie has withstood the ravages of time, so that I hope it will still be there when more people with more sense of purpose and more vision, more concern about the American way of life and doing a decent job with the taxpayer's money, will yet take this step and do the next too, put it to the use for which it is intended (see Map Section for location in Illinois)

MAN AND AIR - THREATS TO PRAIRIE SURVIVAL

By

George P. Hanson

Senior Biologist, Los Angeles State & County Arboretum
301 North Baldwin Avenue, Arcadia, California

Introduction

Although pollution in all forms is increasing everywhere in the world, it is increasing most rapidly in highly industrialized countries where, ironically enough, a high standard of living has given the people a false sense of security, causing them to be wasteful of their natural resources. Fortunately, as man becomes more deeply aware of his environment he becomes more aware of pollution and its many-faceted threats to his existence.

Thus, in the prairie states there is a growing concern with air pollution because of its visible damage to crops. In Southern California, on the other hand, air pollution is something of an old story. It begins with the automobile, so important in an area lacking a rapid transit system, and goes on to include such variables as the high light intensities, low humidity, low rainfall, slight wind movement, and high temperatures, all of which contribute to the formation of dangerous concentrations of air pollutants during the summer and autumn months.

Starting in the morning when the commuters are on their way to work, and continuing throughout a typical day, a slight breeze blows in from the ocean over the seaside communities (our major industrial areas). It continues down the San Gabriel Valley and eastward through the Pomona-Walnut Valley on its way to Riverside and San Bernardino. Like most Los Angeles area cities, these are located in valleys surrounded by mountains. As the breeze blows inland it picks up the primary pollutants which are converted to even more toxic materials via photochemical reactions of the sun. By the time the pollutants have reached Pasadena, Azusa, and Pomona they have been concentrated somewhat and have had sufficient time to interact with each other. The result is eye-smarting, plant-damaging smog.

Although most of the reddish-brown pollution cloud continues eastward on through the valley, some of it enters mountain passes to the north and infiltrates the Angeles National Forest. The main cloud of pollutants proceeds eastward, increasing in concentration and toxicity from the accumulated pollutants of the cities through which it passes until it reaches the San Bernardino area. The pollution cloud up to this point has been riding close to the ground because of a temperature inversion layer. Now its eastward progress becomes partially blocked by mountains. The continued northeasterly breezes and the convection currents along the mountains on the north and east cause a mixing of the warm surface air with cooler upper air at the edge of the mountains. As a result the air pollution cloud filters over the mountains into the San Bernardino National Forest.

Sources of Air Pollution

The sources of air pollution are primarily industry and the internal combustion engine. The phosphate fertilizer industry emits fluoride and oxides of nitrogen (NO_x). Nitrogen fertilizer plants contribute nitric acid and NO_x. Petroleum refineries spew many toxic fumes including sulfur dioxide (SO_2), carbon monoxide (CO), NO_x and various hydrocarbons. Other chemical plants yield particles and gases including hydrochloric acid (HCl), hydrogen fluoride (HF), SO_2, and hydrogen sulfide (H_2S). Various smelting plants discharge SO_2 into the air. Lead mining and concentrating facilities produce lead-containing air pollutants. The paper pulp industry yields H_2S and other sulfur compounds. Electric power plants and other stationary power sources utilizing fossil fuels expel SO_2 and NO_x as well as particulates. The internal combustion engine burning the standard fuels belches lead, CO, NO_x, and hydrocarbons including fuel, aldehydes, and ethylene.

Many of these pollutants act on living material directly upon contact. Others such as NO_x and hydrocarbons, toxic in themselves, become even more hazardous when allowed to interact in the presence of oxygen and sunlight. The reaction products include nitrogen dioxide (NO_2), ozone (O_3), and peroxyacyl nitrates.

How Air Pollutants Damage Plants

Air pollutants damage plants in several ways. Certain pollutants fall on the vegetation in aerosol form or are condensed with dew. Several pollutants, such as HCL, and SO_2 which may combine with water to yield sulfuric acid, produce an acid lesion on the leaf. Most pollutants enter the leaf through the stomates and cause internal leaf damage. When a leaf is actively photosynthesizing, its stomates are open and susceptible to pollutant gases.

Since guard cell action is determined at least in part by the water concentration in the leaf cells and in the outside air immediately adjacent to the stomate, under humid conditions stomates have a larger aperture than in dry air. At a given pollutant level, other things being equal, a plant growing under conditions of high humidity will take in more pollutant and become more severely damaged than a plant growing under arid conditions. Thus, levels of pollutant damaging plants in the Los Angeles area would be even more toxic in the Chicago area.

Symptoms of Plant Damage

Once the pollutants have entered the leaf, each has its own characteristic type of interaction with the plant tissues. In most instances the exact cellular target site of pollutant activity is unknown. Most pollutants seem to differ in their effect on plants, although it is not always easy to distinguish between pollution damage and symptoms due to other causes. The concentration necessary to induce formation of symptoms also varies. For instance, lead at concentrations currently found in nature is not toxic to plants. Plants do, however, take up lead through their roots and concentrate it. The result may be fatal to herbivorous animals which eat the lead-containing plant.

Lead is known to be an accumulative poison, and animals feeding along busy highways might well ingest sufficient lead to be detrimental to them. Recent studies with pigeons (Tansy and Roth, 1970) illustrate quite well the fact that animals living in polluted city areas acquire several times the lead concentrations in their tissues as do animals living in relatively clean country air. Tansy and Roth suggest that the major portion of the concentrated lead is absorbed via the bird's respiratory system. Thus, small animals living along a busy highway could accumulate lead by consuming lead-containing herbage or breathing lead-laden air.

Fluoride air pollutants damaging to plants are hydrogen fluoride and silicon tetrafluoride. These substances are taken through the stomata and absorbed by the mesophyll tissue. From the mesophyll the fluoride moves toward the leaf tips and margins where it accumulates. The characteristic symptom of fluoride damage is necrosis on leaf tips and margins where the fluoride has been concentrated. Animals feeding on plants which have accumulated fluoride in leaves may receive toxic dosages.

Ethylene is considered to be a plant-growth hormone and as such exists in low concentrations wherever there are growing plants. It causes a general reduction in growth, decreased apical dominance, and stimulates lateral development. Symptoms often appear on older tissues first and result in early leaf abcission. In orchids the characteristic symptom is necrosis of the sepals.

Peroxyacetyl nitrate (PAN) is the most prevalent component of the peroxyacyl nitrates and is probably responsible for most of the symptoms caused by them. PAN enters via the stomates and preferentially attacks the spongy mesophyll. These cells collapse and give the leaf a glazed appearance. Since PAN usually leaves the palisade intact, most sensitive dicotyledonous plants show symptoms only on the lower leaf surface, while grasses show symptoms on both surfaces. Attacking leaf tissue of a very specific physiological age, PAN gives many plant species a characteristic banded appearance after several successive days of exposure. After 24-48 hours the glazed appearance may turn bronze or silver. With high concentrations, the tissue may become chlorotic. Subsequent growth of the damaged leaf may result in an indented or pinched area surrounding the injured tissue.

Ozone (O_3), in addition to forming characteristic symptoms on plant leaves, causes reduced growth. Since ozone enters through the stomates and attacks the palisade tissue, the symptoms are usually expressed only on the upper leaf surface. Many species develop pigmentation at the affected area and show a dark stippled

upper leaf surface. In others, the affected cells lose chlorophyll, resulting in a chlorotic or necrotic flecking. Grasses exhibit the symptoms on both surfaces. Under more extreme exposure to ozone large chlorotic or necrotic areas may develop. In contrast to PAN, young leaves are more resistant than older leaves to ozone damage.

Nitrogen dioxide (NO_2) causes growth reduction and defoliation at concentrations often present in polluted areas. Acute symptoms such as chlorotic or necrotic areas occur only with high dosages. The levels of this pollutant in city atmospheres is increasing, however, due to changes in the character of automobile emissions.

Sulfur dioxide (SO_2) enters through the stomates and reacts with water on the moist cell surfaces to form sulfite which is in turn slowly oxidized to sulfate. Chronic exposure to SO_2 may result in toxicity symptoms due to accumulated sulfate, while acute exposure will yield sumptoms of sulfite toxicity. Chronic symptoms include a general chlorosis while acute symptoms are marginal or interveinal spots.

Since the natural air pollutants emanating from most midwestern cities consist of a mixture of all of these contaminants, the syndrome presented by the plant will be complicated. Different species will respond to the air pollution differently because of differeing relative sensitivities to the different pollutants. An excellent review of symptoms developed by various plant species as well as their relative sensitivities to the pollutants has been recently published by the Air Pollution Control Association (Jacobson and Hill, 1970).

Ecological Effects of Pollution

Air pollution is having a detrimental economic effect on agriculture in the nation. Truck crops such as beans, lettuce, and spinach cannot be grown in polluted areas near cities. Orchid growers and other producers of cut flowers must establish their nurseries farther and farther away from large cities. Citrus growers in California and Florida are suffering from air pollution. Many farmers have been forced to move away from pollution sources. Alfalfa and many other farm crops in the midwest are very sensitive to air pollutants and farmers are experiencing damage.

Air pollution is also altering the ecological relationships of plants and animals. Many native midwestern plants such as legumes and grasses are very sensitive. California and other states with native pines have found them to be among the most sensitive of trees to photochemical air pollution, although there is much variation between species. Ponderosa pine and eastern white pine are among the most sensitive. Ponderosa pine dominates much of California's forested lands and is one of the most valuable timber trees. Up to 85% of our ponderosas in the Los Angeles area forests are damaged. Most of these trees may soon die. They appear to be quite sensitive to ozone, which impairs the photosynthetic process and other enzymatic reactions, and also causes premature leaf abcission. And while normal leaves are retained on these trees for 3-5 years, a damaged ponderosa often has only the current year's needles remaining. Thus, the plant is able to make and store less food, and produce less resin. Since resin seems to function as a protectant against bark beetles and certain other diseases, a smog-affected tree is more susceptible to attack by other organisms. The result is premature death. Unless something is done quickly, the ponderosa pine in California may be doomed.

Research to Develop Tolerant Plants

Fortunately, most species have a great wealth of genetic variation in sensitivity to air pollutants. While many ponderosas are dying, others adjacent are quite healthy. We must select and propogate the pollution-tolerant specimens. With ponderosa pines this is difficult because they don't root readily, and grafting is slow and expensive. Hence the forest service is replacing the dying ponderosas with other more tolerant species such as sugar pines, firs, and incense cedar which are apparently capable of withstanding current levels of pollution. At the Los Angeles Arboretum we are currently trying out new ways of rooting ponderosa cuttings using specialized rooting chambers and chemical treatments. We are also attempting tissue culture of these pines with the hope of rapidly propagating pollution-tolerant clonal plant material from which we can later obtain rooted plants.

The mechanism of plant tolerance to air pollutants is not known in most cases. However, Engle and Gabelman (1966), found that tolerance to ozone in onions is due to a single dominant gene. The tolerant plant has sensitive guard cells. When the air pollutant is detected, the stomates close and the plant is protected. Tomlinson and Rich (1968,1969) believe that lipids may be involved, at least in tobacco. They, and others, have found that ozone tolerance in most plants is due to two or more genes. Our studies with petunias implicate greater leaf thickness and ascorbic acid (Vitamin C) concentration with ozone tolerance. Preliminary data from petunias indicate that two or more genes are involved and that sensitivity is partially dominant to tolerance in gene action. Breeding programs are currently under way with many plant species to develop smog-tolerant varieties.

Application to Prairie

Hopefully, a great wealth of genetic variability in response to air pollutants also exists within each species of the native prairie flora and fauna as well as considerable variation between species. Several participants at this conference have discussed prairie establishment or maintenance of relic prairies within a city. It will be interesting to see if some species are eliminated by the air pollution associated with these urban centers. Due to their possibly relatively short generation times (compared to pines), the prairie natives may be better able to adapt to man-made air pollution. Thus, the changes in the prairie ecosystem may not be as severe as those we are experiencing in Southern California.

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Editorial Note:

This paper has value beyond merely indicating the kinds of damage to be expected to plants by air pollution (which must be watched for, even though the specific symptoms reported here are based of course primarily on cultivated vegetable and flower crops including tobacco and petunias). The paper raises four points:

1. That even restored prairie may be endangered by environmental deterioration.

2. That prairie, rich in species, may well provide many specifically sensitive indicators of particular types of pollution.

3. That prairie studies, if long continued, can shed light on the relation of disturbance to population turnover and, in turn, the relation of this turnover to genetic selection for smog resistance.

4. That the clonal propagation route to smog resistance could promote genetic uniformity in native vegetation which may spell less resistance to new threats in the future.

A REQUIEM FOR THE PRAIRIE[1]

By

Hugh H. Iltis

Professor of Botany

University of Wisconsin, Madison

It is a particular privilege to talk to an agricultural convocation, because, for better or worse, you who farm and you who teach land use hold the key to either the continuing destruction of the biosphere and its diversity, or to a birth of ecological sanity which will allow life and man a continuing evolution.

I wish to voice three basic concerns:

First, because our species, Homo sapiens, evolved in nature, and was selected by nature, we need nature to survive.

Secondly, because of our technological successes in conquering nature, we have been completely preoccupied with progress, progress which to agriculture has meant ever-increased production of goods and food to feed more and more people. This means ever-increased destruction of the natural environment which made us. Our preoccupations have made us not only rich and civilized, but also arrogant and blind to inescapable biological realities. If we wish to continue our evolution, a radical shift from an exploitive to an ecological philosophy is a most urgent business.

Lastly, only undisturbed ecosystems, such as virgin prairies or forests, can show us their vast ecological complexities. Such untamed lands are desparately needed for teaching and research, for a balanced stable environment and a beautiful and healthy world. Thus, it is one of the prime responsibilities of progressive agricultural education to insure the survival of the last few remaining undamaged prairies and forests for posterity. The greatest contribution that any university can make to human culture is the establishment of hundreds of scientific preserves, and the training of ecologically sophisticated students.

Man needs nature, nature is being eliminated, and what can we, what must we, do about it?

Now, how true is it, really, this human need for nature, over and beyond the nature that gives us food? Do we need wilderness? Do we need flowers? Do we need beauty? Do we need National Parks?

Surely technology has promised us a post-evolutionary heaven in which wild nature has but a very minor role. Molecular biology, too, has gleeful visions of genetic manipulations of DNA which would change the face of all creation and recast man into a "perfect" image. Others cheerfully dream about a world with unlimited opportunity for at least 40 billion people, living in giant, automated cities. There is no doubt that science and technology have undreamed of potential for food production. But the quality of living, not the quantity, is what counts. Any one of us, if not blind, who has hunted for prairie flowers in Illinois, fished in the Mississippi, explored the Peruvian Andes or on the Mexican Plateau, or tried to find a tree growing in Brooklyn, knows that life's diversity is what keeps the world from being dull!

Yet, in 20 or 30 years, it will all be over for much of this exuberant biotic wealth. The crisis for all the living and for a high quality environment for man is here and now. Except for masses of people, corn and cows, the world of the near future promises to be flower-less, animal-less, and lifeless. The next century will be a nightmare world of steel and concrete, of algae steaks and yeast pies; and the day may well come when our great-grandchildren will hold hands in a circle and sing:

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[1]Address presented to the Agriculture Convocation, Kansas State University, Manhattan, Kansas, April 6, 1967, reprinted with permission from the Prairie Naturalist, Vol. I, No. 4, December, 1969, pp. 51-57.

"Spring has sprung
The grass has ris
I wonder where the flowers is"

and wish they could see some. And by then it will be too late.

Is there any one among us who would doubt that we, and especially our children, need a good helping of wild nature to walk in, to cherish, to love?

Granted, then, that we all love flowers and birds, and instinctively seek nature even if in a garden. But is it enough to say "We need" - "we love?" The skeptics want to know "why?" And the technicians of exploitation are not impressed by sentiment, but by dollars and profit, by board feet and yield per acre.

How can we defend sanctuaries for prairie flowers and young birds, and mountain lions and pitcher plants? And especially, a million acre National Park for buffalo and prairie grass? How can we defend such luxury when our world is plagued with hunger? How can we defend it for science, to say nothing of other reasons. Can we defend, in short, a truly human environment for purely selfish human reasons?

Let us examine our evolutionary history. Some 4 or 5 billion years ago, on some fateful day, lightning struck water, ammonia, and carbon dioxide and the first organic molecules were born. Eventually, after another 1000 million years, these substances, now self-duplicating, organized themselves into cells, and life was on its evolutionary way. Perhaps a 1000 million years ago came the first invertebrates, 500 million years ago the first land plants and aquatic vertebrates, and 250 million years ago the coal flora with its terrestrial vertebrates was living in Kansas, characterized by giant dragonflies and fish, and 40 foot horsetails. Next came the dinosaurs, 150 million years ago, and, when they became extinct, the mammals arrived, to evolve into monkeys, apes, and finally into clothed, intellectualized, transformed apes, the unique species Homo sapiens, of which all of us are members.

Now Man is indeed unique! But it should never be forgotten that he is a unique animal! He is the result of 2000 million years of evolution at the cellular levels, of over 500 million years as a vertebrate, of over 100 million years as a mammal, of 45 million years as a primate, of over 15 million years as an ape, and, at most, of but 2 million years as a prehuman.

The refined human neurological and physical attributes are even more recent, only a few hundred thousand years, perhaps at most 5,000 or 10,000 sexual generations old. All of our major physio-chemical patterns, those ancient, basic, mysterious chemical frameworks of the human animal, controlled by an ancient autonomic nervous system, evolved not in civilization, but in nature.

Physically, like the apes, we are programmed for wild tropical or subtropical nature. But culturally, especially away from the equatorial regions, over the past 10,000 years we have become dependent on, and culturally adapted to, towns and cities. Thus, even though we live in recent inventions called houses, for our physical and mental well-being nature in our daily life is an indispensable biological need. As proud as we are of our amazing cultural uniqueness, every basic adaptation of the human body, be it the ear, the eye, the brain, the gut, yes, even our psyche and our sex life - for proper functioning demands an environment similar to the one in which these structures and behavior patterns evolved over the past 100 million years through natural selection. For millions of generations, as George Gaylord Simpson points out, our monkey ancestors with faulty vision who misjudged distance and missed the branches they jumped for, or who did not hear the approach of a carnivore, died, and failed to become our grandmothers. Only those that were adapted to nature contributed to our gene pool.

The significance of this to understanding man or any other living thing is clear. George Schaller illustrated in "The Year of the Gorilla" that, if we study gorilla behavior in a zoo, the animal is an incomprehensible, dangerously erratic brute. But if we study gorillas in their evolutionary habitat, in the tropical forests of Africa, they are shy, mild, alert, and well-coordinated bundles of adaptations. Neither gorilla nor man can be evaluated, understood, or kept healthy out of context of the evolutionary environment that selected them.

Cultural expressions of these subtle biological needs of man are everywhere. In our houses, we try to imitate tropical climate, the setting of our geological past - warm moist air and green plants and even animal pet companions. If we can afford it, we may even build a greenhouse next to the living room or buy a place in the country. The specific human reactions to natural beauty and diversity are as yet poorly understood. They have not been much studied. Yet our needs are clear from our preferences. We have plastic flowers in every bank, and green leaves imprinted even on the "puke bag" they give you on the airplane. From the standpoint of evolution, like the need for love and loving, human needs for nature, for natural diversity and natural beauty, must have a genetic basis. The tremendous compulsive power of these drives alone suggests this clearly. Thus Tennyson's line, "Nothing in nature is unbeautiful," takes on new significance. Woods and prairies, clean air and unpolluted waters, flowers and butterflies, gardens and fields, yes, and vast National Parks, are indispensible human needs.

How can we plan to satisfy these needs? How can we plan for a good world or a high quality environment? Clearly we must accept man's dependency on nature. It follows then that ecologically-based environmental planning, i.e., a true human ecology, is the one and only cornerstone of a sane and human world. Only in this context can we discuss resource management and environmental health, or argue whether preservationists are sentimental, or exploiters practical or short-sighted.

Then how are we to define the best environment for man? Is it not one in which the human animal can have maximum contact with the natural environment in which it evolved and for which it is genetically programmed, without sacrificing the many advantages of civilization? That is, our optimum human environments must represent a compromise between our genetic heritage, which we annot deny, and the fruits of civilization, which we are loath to give up. Of course, some proclaim a blind faith in our ability to adjust our genetics as well as our culture to the destruction of the environment. But this is impossible! Not because man cannot change his needs, but with his long life span and genetic limitations, he could not possibly change them fast enough. Yet today man is modifying his environment (especially in the large cities) so rapidly that soon all his adaptations will be out of phase.

But suppose that man could change to keep up with his changing modern environment. Man would then evolve smaller ears, less sensitive eyes, a toleration to crowding and pollution, and, as a consequence, lose his most precious sensory values. The appreciation of life and of living, the enjoyment of nature, art, and music, for example, would lose all meaning. Furthermore, these genetically-fixed ecological idiots of the future, like many of our culturally-fixed ecological idiots of today, would then control the fate of the living world, doubly accelerating its deterioration into a human pigsty.

We cannot radically change our physiological adaptation. We cannot change our genetically based needs. But we can modify our culture, and without too much trouble. And we had better start doing this soon. The need is great to reformulate some of our most cherished cultural concepts, to rethink the most sacred agricultural dogmas.

For all is not well on this spaceship earth. There are now too many people, wanting too many things. And in 10 years, a billion more! An old Wisconsin hunter said, "The older I get, the less and less I get interested is shooting animals, and the more and more I get interested in shooting people."

The population explosion, technology, and the chemical revolution threaten to make Man the one animal who, by conquering nature, is making the earth unfit for all. The more complex technology becomes, the more far-reaching are its destructive effects. To assess these effects, to stop or reverse them, is exceedingly difficult. Even to ask pertinent questions, or to expect sensible solutions, has become almost impossible. Technological success has corrputed our ability to view the human animal in proper perspective.

The second point I wish to make is a practical one. If we need nature and its diversity in order to survive as a quality civilization, we must accept nature as the <u>most precious</u> of all human possessions; and the main responsibility of our educational system, in the agricultural schools especially, is to train people not only in its exploitation, but also in its preservation.

It would be blind not to acknowledge the immense debt of modern man to the destruction of nature. The fabulous inventiveness of modern agriculture has allowed the cultural exploitation that is here today. It has made our very civilization possible. Agricultural technology, from Liebig and the gasoline engine to hybrid corn and pesticides, has crashed the barriers to increased production. Yet we must now assess its long-term effects.

We must, I think, learn to accept the fact that agriculture and forestry will have to spend as much time correcting or preventing the ecological consequences of human activities, as in abetting the increased exploitation of nature.

But we are still too preoccupied with an expanding economy, and with a "progress" where production and quantity, not quality, are the targets. Increased economic growth was, and is, after all, largely dependent on the rape of the redwoods, the destruction of buffalo and prairie, the exploitation of the sea, the pollution by DDT, and the use of fossil fuel. To continue all this madness, our schools must continue to train properly indoctrinated citizens, not those that love flowers or prairie dogs!

So, now that buttercups are rare, and springs silent, why study them? The ever-increasing emphasis on technology and (until recently) the continued deletion of Natural History from the curriculum has slowly but surely produced generations of children which can at most distinguish a dandelion from a daisy, but to whom the fields and woods are a closed book. And where are they to learn? Teacher doesn't know, the public doesn't care. And most city kids have ceased to wonder at natural beauty for other reasons as well - the simple unavailability to city schools of woods with song birds, of prairies with flowers. How many high-schools in Kansas or North Dakota have school prairies? Some forgotten unplowed 40 acres used just for teaching? For that matter, how many colleges?

And the college contingent has fared little better. In many parts of the United States, the crucial role in the survival of wild nature is relegated to the farmer, and to bureaucrats who control the fate of remnants of public wild land, be they planners or highway engineers. Yet in their education, natural history has been neglected. Agronomists may get Ph.D.'s without knowing one grass from another. The agriculture student is often shortchanged by his curriculum in his preparation for a sensible future. And where are the agricultural beatniks to tell their professors "this is enough."

We need a Berkeley on our agricultural campuses to force an intellectual change. I don't think agricultural schools will die, but they might just possibly fade away. And if we continue in the old tracks of progress, production, and pounds per acre, the decline of the agricultural schools will be well deserved. Farm boys can return home with a B.S. and little more knowledge about flowers or ecology than what 2-4D will do to the "weeds" on the back forty. Yes, good high yields per acre, assured by DDT, will outvote any prairie rose in need of living bumble bees for pollination.

Such is the cultural intensification of environmental ignorance. It is very dangerous. For what American children and adults neglect to learn about American flowers or landscapes, or Russian or Chinese children about theirs, may bear strange and disastrous fruits in our country as well as in foreign lands. It is especially dangerous in the United States, since we, as the richest country in the world, have now the power of enforcing, on other peoples - economically or militarily - our economic ways, to change the face of the earth - which means destriction of biotic diversity. And in the tropics especially, which are ecologically so fragile, the results are catastrophic.

I could talk a great deal about the importance of diversity to natural and agricultural stability, but Charles Elton has explained it so well in his book, "The Ecology of Invasions by Plants and Animals," which should be required reading for all. The fate of this diversity represents the fate of life, of continuing evolution, and therefore very probably of Man himself.

Must we destroy this diversity without heed to the other values, including often direct agricultural ones? By chainsaw or pesticides, by cow or plow, by sewer or chimney, we are exterminating thousands of species, whose roles in the web of life we cannot even guess at, whose uses for Man we do not know, and will not know, for many years to come. As a scientist, I cannot say when or how, or how much; but again as a scientist, I can say: Without knowing, dare we take that risk?

We have discussed elsewhere the scientific utility of the American Prairie and what it can teach us of evolution. We have marvelled at the beauty of its animals and plants, their bright colors and wondrous shapes, whose meaning often we cannot yet fathom. And we have mentioned the practical values in agriculture that this ancient and diverse biological community holds for the human species. It is clear that prairies have value to man far beyond their price tag in dollars.

There is, however, one additional and overriding urgency to prevent the permanent extinction and subjugation of the living landscape. Taine, the French historian, has said that "the body of man in every country is deeply rooted in the soil of nature." "Give the philosopher a handful of soil, the mean annual temperature and rainfall, and his analysis would enable him to predict with absolute certainty the characteristic of the nation."[2] We, in this overly rich country have forgotten this basic truth. We have worshipped the high standard of living, but have forgotten that ultimately it flows from the land. Until 30 years ago, as a people we identified closely with the pioneers, their hardships and devotion, their environment of hostile Indians, of cattle and cowboys, of stars over the boundless oceans of waving grass. The prairie was their garden in more than one way. The marvel of six feet of top soil and the magnificance of millions of buffalo, the sweat of the breaking of sod and the harvest of vast yellow fields of wheat are part and parcel of our cultural history. Without the prairie, we, the American people of today, cannot understand where we came from, what we are, and where we are going.

When you professors were young, there were still virgin prairies in abundance, even in Illinois and Wisconsin. When you were young, you were still part of the tradition that made your life. Today, in the whole prairie state of Illinois, there are hardly 40 acres of deep-soil prairie left! Here, the "landscape," which to all people of all lands, and not only to the poet, was "a mother that never dies," has become subjugated and killed.

Yet the landscape as it was when the settlers came is still vitally important to our educational process, to our culture. By our avarice, we are losing touch with what made the Midwest what it is today, not only with our land resources which made us wealthy, but which also made our culture, our life. What is to satisfy the simple unspoken needs of humanity to keep in touch with its ancestry? We need landscape, fenceless wild lands, to know how they, our forefathers, lived and worked. We need wilderness to know where we, the human species, came from. We are rapidly becoming cultural and evolutionary orphans, a people without a cultural past, a species with meaningless adaptations.

Let it be said of the prairie states, of its many Universities, that they led the way to save for America and the world one of its richest biotic communities, and for humanity, one of its grandest sights. Let it <u>never</u> be said that the prairie states let the prairie die.

Let us plan for at least four big National Parks. A Shortgrass Park in the Dakotas, and a Sandhills Park in Nebraska, each over one million acres, a Llano Estacado National Park near Lubbock, Texas, and a Tallgrass Prairie Park of over 300,000 acres in the Flint Hills near Manhattan, Kansas. I have a dream of a Prairie Research Institute (an institute of advanced ecological studies) to train students in the ecology and taxonomy of the prairies and Great Plains. I have a dream of a system of prairie hiking trails, of school prairie preserves, and of a rich and enriching landscape.

Until we have preserved for our children the biotic wealth of the prairies, we cannot, in truth, sing a halleluja to civilization, for the vast prairie is close to death. We have come here instead for a solemn requiem. The word <u>requiem</u> comes from the mass for the peaceful repose of departed souls in a new life, "<u>Requiem aeternam dona eis, domine</u>," "give them eternal peace, oh Lord." Let us remember that in singing a requiem for the prairie, we hope yet to rejoice in its future!

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[2] J.J. Ingals in Grass, 1948 Yearbook of Agriculture, USDA, p. 7

We, who understand that the basis of human culture lies in the past, we who believe that man does not live by bread alone, must pledge our conservational ideals with concrete action. That magnificent Prairie National Parks shall thrive is our responsibility. That wild prairie, in a series of parks from Canada to Texas, shall live and bloom for 10,000 years to come, is our dedication to our culture and our legacy to our children, so that they, on a warm spring day, can feel peace in a sea of grass, watch a bee visit a shooting star, hear a sandpiper call in the sky, and marvel at the incomprehensible symphony of life.

APPENDIX A

A PRAIRIE DIRECTORY

A Beginning on which to build;
See list of addresses following for individuals mentioned.

I. Preservation, restoration, propagation, management, plant lists and interpretation-- some contact people:

General

Nature Conservancy, Midwest Regional Office, 329 West 15th Street, Park Terrace Bldg., Minneapolis, Minn. 55403. (Most states have local chapters.)

Prairie Chicken Organizations-- Drs. Frederic and Frances Hamerstrom, Rl, Plainfield, Wis.

Inventory of Natural Areas-- Dr. Paul C. Lemon, A.I.B.S., 3900 Wis. Ave, Wash., D.C. 20016

Wisconsin

Soil Conservation Service-- Bill Briggs

Dept. Natural Resources-- Cliff Germain, Bob Smith, Ed Frank, Walter Jacobson.

UW Arboretum, incl. seed suppliers--Roger Anderson

Waukesha County Parks--Jerome Schwarzmeier

Milwaukee Whitnall Park--Harold Rock

Nature Conservancy--Paul J. Olson

UW-Parkside--Eugene Gasiorkiewiez

Illinois

Nature Preserves Commission, 819 N. Main St., Rockford 61103 - Mr. George Fell

Prairie Path, P.O. Box J., Wayne, 60184

Peacock Prairie--Mrs. Olof Dahlskog

Morton Arboretum--Ray Schulenberg, Floyd Swink

County Forest Districts--Robert Prager, Charles Westcott

Ill. State Museum, Springfield

Knox College-- Peter Schramm

N. Ill. University- Bullington, Wade

Dept. Natural Resources--Natural Areas--John Schwegman

N.E. Ill. State College--Robert Betz

So. Ill. University-- R. Mohlenbrock

Ill. Nat. Hist. Surv. - Evers

Ohio

Aullwood Nature Center, Dayton

Dept. Natural Resources, Columbus 43215 - Ralph Ramey

Michigan

Universities--Scharrer, Thompson, Voss, Bland

Indiana

Dept. Natural Resources, Div. of Nature Preserves, Indianapolis, 46204

Nature Preserves Board, Univ of Notre Dame

Missouri

Dept. Natural Resources, Columbia--Don Christisen, A. Karl Slagle

Prairie Foundation, P.O. Box 200, Columbia 65201

University of Mo., Biology Dept.--Clair Kucera

Iowa

Colleges & Universities--Messrs. Landers, Christiansen, Cawley, Lyon

Minnesota Minn. Nature Conservancy - Bray

Univ. Minn.--Messrs. A.G. Johnson, T. Morley; Ms. Margaret Smithberg

Dept. Natural Resources, St. Paul-- V.W. Hella

The Dakotas N. D. Prairie Research Ctr. - Duebbert

Devil's Lake, P.O. Box 159-D, 58301

State Highway Dept., N. D.-Sengpiel, Deinuis

Prairie Naturalist--N.D. Univ. Inst. Ecol. Stud.--Grand Forks 58201 - M. Wali

S.D. Univ. -- Webster Sill, Jr.

S.D. Game Research, Rapid City--B. Gastner

Nebraska Growing grass - Jim Wilson

University at Lincoln, Botany Dept. - S. Salac

Dept. of Roads, Lincoln - Gray SCS - Jensen, Shiflet, Hutchinson

Kansas

Third Midwest Prairie Conference, 1972- --Lloyd C. Hulbert, Div. Biology, Kansas State Univ., Manhattan, 66502

Fort Hays State Univ. - Hulett, Fleharty, Tomanek

Kansas Wildlife Federation, R. 1, Wamego 66547 - Ted Cunningham

Texas

Highway Dept., Austin - Sherrod

Colorado

State Univ. - Ward, Moir

Oklahoma

I. B. P. and University - Risser

Saskatchewan

Sask. Nat. Hist. Soc., Regina

Univ. Sask. Biology Dept.--G. F. Ledingham and R. Dix, Regina

Leaflets on starting prairies, collecting seed and propagating prairie plants are available from a number of parties including:

Nebraska--Jim Wilson, S. Salac, T. Shiflet

Texas--Sherrod

Iowa--Landers, Christiansen Missouri - Christisen

Illinois--Schulenberg

Milwaukee-Wis. - Rock

II. Prairie Movies

A Prairie Should Be Forever (Color, sound, 15 minutes.) --Missouri Prairie Foundation, Box 200, Columbia, 65201

The University of Wisconsin Arboretum (Color, sound, 40 minutes.) B.A.V.I.#6206, UW 53706

Wildflowers of the Upper Midwest- The Prairie (Color, sound, 18 min.) B.A.V.I.#6841, UW 53706

Berkeley Prairie, Illinois--William E. Sproat Adv., Inc., 230 N. Michigan Ave., Chicago, 60601

Prairie Promenade--Film Secretary, S. Dakota Dept. of Game, Fish and Parks, Pierre, 57501 (Heavy demand restricts it to in-state requests).

Prairie: Physical Factors and Plant Adaptations (81-7197) and Animal Adaptations (81-7205)--both 4 min. color film-loops for college or high school. The Ealing Corp., Cambridge, Mass. 02140.

Wisconsin Prairie Heritage (colored slides with script; kit for 7th grade teachers)--Curriculum Devel. Dept., Madison, Wis., Public Schools 545 W. Dayton St. 53715

Colored slide sets are often available from State Departments of Natural Resources and institutions like the UW Arboretum.

III. The Prairie Bookshelf--Some Selected General Readings.
(A more extensive list of books and papers has been compiled by Dr. Ronald L. Stuckey, Curator, Herbarium, The Ohio State University, Columbus.)

Allen, Durward L. 1967 Life of the Prairies and Plains. McGraw-Hill.

Angle, Paul McClelland. 1968. Prairie State: Impressions of Illinois, 1673-1967, by Travellers and Other Observers. Univ. Chicago Press.

Anon. 1961. Madison School Forest. Curric. Devel. Dept., Madison Public Schools, 545 W. Dayton 53715

Anon. 1966. Parade of Plants: Fields and Prairies. Leaflet, Wis. Dept. Nat. Res., Box 450, Madison 53701

Archer, S. E. and C. E. Bunch. 1953. The American Grass Book. Norman, Okla.

Christisen, D. M. 1969. National Status and Management of the Greater Prairie Chicken. Trans. 34 N. Am. Wildl. and Nat. Res. Conf. 207-217. Avail. from Mo. Prairie Fdn.

Costello, D. F. 1969. The Prairie World. Crowell

Courtenay, B. and J. H. Zimmerman. 1972. Wildflowers and Weeds. Van Nostrand-Reinhold.

Curtis, J. T. 1958. Vegetation of Wisconsin. Univ. Wis. Press

Farb, Peter. 1968. The Face of North America. Harper

Fassett, Norman C. 1939. The Leguminous Plants of Wisconsin. Univ. Wis. Press

Garland, Hamlin. 1965. Boy Life on the Prairie. Repr. 1st. ed. 1899. Lincoln

Gregg, Josiah, ed. by Milo M. Quaife. 1967. The Commerce of the Prairies. Repr. 1926 ed., Lincoln

Grube, G. E. Some suggested alternatives to the bluegrass lawn. Omaha, multi. Avail Mo. Pr. Fdn.

Guard, Wayne 1968. The Great Buffalo Hunt. Lincoln

Haines, Francis. 1970. The Buffalo. N. Y.

Hudson, Lois P. Reapers of the Dust.

Irving, Washington, ed. by Francis McDermott. 1962. A Tour of the Prairies. Norman

Jackson, Charles Tenney. 1967. The Buffalo Wallow: A Prairie Boyhood. Lincoln

Kucera, Clair L. 1961. The Grasses of Missouri. Univ. Mo. Press, Columbia

Leopold, Aldo. 1949. A Sand County Almanac. Oxford; Ballantine

March, Randolph B. 1968. The Prairie Traveler: A Handbook For Overland Expeditions. Repr. 1859 ed., Williamstown

Mathews, John Joseph. 1961 The Osages: Children of the Middle Waters. Norman

Mathews, John Joseph. 1968. Wah' Kon-Tah: The Osage and White Man's Road Norman

McDermott, John Francis. 1968. (ed.) Tixier's Travels on the Osage Prairies. Norman

Peattie, Donald C. Prairie Grove

Reich, Binda. 1971. Guide to the Arboretum Prairies. Friends of the U.W. Arboretum, Madison

Rickett, Theresa C., ed. by E. M. Palmquist and C. L. Kucera. Wild Flowers of Missouri. 1954 Columbia

Roe, F. G. 1972. The North American Buffalo. 2nd ed. Toronto

Rolvaag, Ole. Giants of the Earth

Rydberg, Per Axel. 1971. Flora of the Prairies and Plains of Central North America. Repr. 1932 ed., 2 Vols., N. Y.

Schramm, Peter (ed.). 1970. Proc. Symp. on Prairie and Prairie Restoration, Knox College, Galesburg, Ill. Biol. Field Sta. Spec. Pub. 3 (Meeting held Sept. 14-15, 1968.)

Schwartz, Charles W. 1944. The Prairie Chicken. Jefferson City

Sears, Paul B. 1969. Lands Beyond the Forest. Prentice-Hall

Spaulding, George F. 1968 (ed.) On the Western Tour with Washington Irving. Norman

Stevens, W. C. 1961. Kansas Wildflowers, 2nd. ed. Univ. Kansas Press, Manhattan

Swink, Floyd. 1970. Plants of the Chicago Region. The Morton Arboretum, Lisle, Illinois

Watts, May Theilgaard. 1957. Reading the Landscape. Macmillan

Voss and Eifert. Illinois Wildflowers. State Museum, Springfield

Weaver, J. E. 1954. The North American Prairie. Johnson

Weaver, J. E. 1965. Native Vegetation of Nebraska. Univ. Nebr. Press, Lincoln

Weaver, J. E. 1968. Prairie Plants and their Environment. Lincoln

Weaver, J. E. & F. W. Albertson. 1956. Grassland of the Great Plains. Lincoln

Wilding The Little House on the Plains

Wilson, Jim, Alice and Steven. 1967. Grassland. Wide Skies Books

APPENDIX B

SECOND PRAIRIE CONFERENCE PARTICIPANTS AND INTERESTED PARTIES

Adams, Prof. Mike
UW Botany Dept.
Madison, Wis.

Allen, Prof. Tim
UW Botany Department
Madison, Wis.

Alexander, Dr. John D.
Department of Agronomy
N-407 Turner Hall
University of Illinois
Urbana, Illinois 61801

Anderson, Dr. and Mrs. Roger C.
U.W. Arboretum
1207 Seminole Highway
Madison, Wisconsin 53711

Angstrom, Cy
Box 282
Kanawha, Iowa

Antonioni, Mary Ellen
1134 Jenifer Street
Madison, Wisconsin 54704

Archbald, Dr. David
525 West Dayton St.
Madison, Wisconsin 53715

Ashbaugh, B. L.
Genessee Co. Parks and Recreation
G5055 Branch Rd.
Flint, Michigan 48506

Atkins, M. D.
6120 Wright St.
Arvada, Colorado 80002

Atwell, Susan H.
2501 N. 7th St.
Fort Dodge, Iowa 50501

Aullwood Nature Center
Dayton, Ohio

Ause, Bruce, Director
Environmental Learning Center
Red Wing, Minn. 55066

Bachant, Joseph P.
Olentangy Wildlife Experimental Station
8589 Horseshoe Rd.
Ashley, Ohio 43003

Banaszak, John
406 North Park St.
Westmont, Ill. 60559

Barger, Dr. G. L.
711 Gramax Bldg.
Silver Spring, Maryland 20910

Baumgartner, Mr. and Mrs. Fred
Biology Department
U. of Wis.
Stevens Point, Wisconsin

Bennett, James P.
HRVC, 105 White Plains Road
Tarrytown, N. Y. 10533

Betz, Robert F.
Northeastern Ill. State College
Bryn Mawr and St. Louis
Chicago, Ill. 60625

Birkenholz, Dale E.
Dept. Biol. Sci.
Ill. State Univ.
Normal, Ill. 61761

Bland, Miss Marilyn K.
U. of Michigan Botanical Gardens
1800 N. Dixboro Rd.
Ann Arbor, Mich. 48104

Blenz, David
Box 247
Lemont, Ill. 60439

Blick, Larry N.
Assistant City Manager
Municipal Building
Boulder, Colorado 80302

Bock, Dr. Jane
Department of Biology
University of Colorado
Boulder, Colo. 80302

Boehman, Sr. Cecile
5915 Erie St.
Racine, Wis. 53402

Boon, Wm. C.
1319 Clark
Ames, Iowa

Boyd, Hugh
Canadian Wildlife Service
Eastern Region H. Q.
Highway 31
Ottawa 1, Ontario, Canada

Boyd, Ivan L.
Box 182
Baldwin City, Kansas 66006

Bragg, Thomas
2131 Prairie Fld. Pl.
Manhattan, Kansas 66502

Brennan, Kathleen M.
1538 N. Leamington Ave.
Chicago, Ill. 60651

Briggs, Mr. Wm. M.
SCS, Box 4248
Madison, Wis. 53701

Brigham III, E.M.
RR4
Red Wing, Minn. 55066

Bray, Edmund C. Chmn., N. C.
3300 University Ave., S.E.
Minneapolis, Minn. 55414

Brock, J. H.
Texas Agricultural Experiment Station
Lubbock, Texas

Brookes, I.
Geography Dept.
York University
Toronto, Ontario, Canada

Bryson, Reid
Envt. Studies Inst.
UW
Madison, Wis. 53706

Bullington, Robert A.
Northern Ill. University
DeKalb, Ill. 60115

Burk, Dr. Myrle M.
RR2
Waterloo, Iowa 53701

Burton, J.C.
Nitragin Co., Inc.
3101 W. Custer Ave.
Milwaukee, Wis. 53209

Cabonis, Mrs. John B.
1603 Elder Lane
Des Moines, Iowa 50315

Campbell, H. Dean
113 State Office Bldg.
Springfield, Ill. 62706

Campbell, Marilyn F.
Forest Glen Preserve
R.R. 1
Westville, Ill. 61883

Carl, James D.
Dept. of Geology
State University College
Potsdam, N.Y. 13676

Carlson, Mrs. Henry
1105 Medaff St.
Naperville, Ill.

Carlson, Dr. Margery C.
2308 Hartzell St.
Evanston, Ill. 60201

Cawley, Dr. and Mrs. Edward T.
Biology Dept.
Loras College
Dubuque, Iowa 52001

Cheney, Mrs. David
6214 Highlands Ave.
Madison, Wis. 53705

Christiansen, Dr. Paul A.
Department of Biology
Cornell College
Mount Vernon, Iowa 52314

Christisen, Donald M.
Rsch. Sec. Mo. Dept. of Cons. Bldg.
Bouchelle and Williams Sts.
Columbia, Mo. 65201

Christoph, Dr. Roy J.
Dept. of Biology
Carroll College
Waukesha, Wis. 53186

Ciolac, Catherine J.
Morton Arboretum
Lisle, Ill. 60532

Clarage, Mr. and Mrs. James B.
14025 King Rd., Rt. #2
Lockport, Ill. 60441

Clarke, Michael G.
Development Research Associates, Inc.
1740 Cherry Street
Philadelphia, Pa. 19103

Cockerill, Mrs. Jerome
Librarian, Mo. Dept. Cons.
P.O. Box 180
Jefferson City, Mo. 65101

Cole, Mrs. Marian H.
1224 Norman Lane
Deerfield, Illinois 60015

Conners, Ed
Colorado Open Space Council
5850 East Jewell Avenue
Denver, Colorado 80222

Costello, Dr. David F.
c/o Thomas Crowell Company
201 Park Avenue South
New York City 10003

Cottam, Dr. and Mrs. Grant
329 Birge Hall
Madison, Wis. 53706

Craig, Paul R.
2300 So. 31st St.
Illinois Div. of Highways
Springfield, Ill. 62700

Cull, Miss Irene
803 N. Ashland Ave.
Peoria, Ill. 61604

Cunningham, Mrs. Mary
2760 Marshall Pkwy.
Madison, Wis. 53713

Cunningham, Ted
Kansas Wildlife Federation, Inc.
RR 1
Wamego, Kansas 66547

Dahlskog, Mrs. Olof
1030 Pleasant Lane
Glenview, Ill. 60025

Davidson, Donald
Wis. State University
Superior, Wis. 54880

Davies, Kenneth
4600 Osage Drive
Boulder, Colo. 80302

Dawson, Gar
300 Femrite Drive
Madison, Wis. 53716

Deinuis, Duane C., Landscape Coord.
N.D. Highway Dept.
Bismarck, N.D. 58501

Dennis, John
2667 Milwaukee St.
Madison, Wis. 53704

Dewalt, Warren R.
624 Wellner Rd.
Naperville, Ill. 60540

DeWitt, Cal.
Biotron
U. of Wis.
Madison, Wis. 53706

Dix, Ralph
Dept. Biology
Univ. of Sask., Regina, Sask, Canada

Drozd, Michael
Courthouse
Port Washington, Wis. 53074

Duebbert, Harold F.
P.O. Box 1747
No. Prairie Wildlife Rsch Ctr.
Jamestown, N.D. 58401

Duffield, Wm.
R.R. #2
Eaton, Ohio 45320

Dull, Mrs. Sharon
C/O U.S. Forest Service
Columbia, Mo.

Dyas, Robert W.
Dept. of Landscape Architecture
Iowa State University
Ames, Iowa 50010

Eaman, Tom
Soil Conservation Service
12417 Federal Building
Denver, Colo. 80202

Earley, Emily H.
602 State Street - U. of Wis.
Madison, Wis. 53706

Eilers, Henry E.
1302 Union
Litchfield, Ill. 62056

Eilers, Dr. Larry
University of Northern Iowa
Cedar Falls, Iowa

Eishmeyer, Bill
UW Botany Department
Madison, Wisconsin

Ellarson, Robert
UW-Russell Labs., Dept. Wild-life Ecology
Madison, Wis. 53706

Ellison, Richard A.
Medora Ranger District
Custer N. Forest
Dickinson, N.D. 58601

Emlen, John T.
Zoology Dept. - U.W.
Madison, Wis. 53706

Erickson, Mrs. Robert
3328 N. Main St.
Racine, Wis. 53402

Evers, Dr. Robert
Illinois Natural History Survey
Natural Resources Bldg.
Urbana, Ill. 61801

Fambeurger, George
SCS
Oshkosh, Wis. 54901

Farmer, Larry
R.R. 2
Le Mars, Iowa 51031

Fehrenbacher, Dr. J.B.
Department of Agronomy
N-409 Turner Hall
College of Agriculture
University of Illinois
Urbana, Illinois 61801

Fell, Mr. and Mrs. George B.
819 North Main St.
Rockford, Ill. 61103

Fellows, Paul
Ill. Dept. of Conservation
Springfield, Ill. 62700

Fischbach, Mrs. Thomas
1206 Frisch Rd.
Madison, Wis. 53711

Fisher, Mrs. Ed. L.
617 Greendale Rd.
Sheboygan, Wis. 53081

Fisher, Mrs. Oneita
Rt. 2
Keota, Iowa

Fleharty, Dr. E.D.
Dept. Biological Sciences & Ag.
Fort Hays Kansas State College
Hays, Kansas 67601

Fleming, Mrs. Rosemary
U.W. Arboretum
1207 Seminole Highway
Madison, Wis. 53711

Frank, Edward J.
Dept. of Natural Resources
Box 450 Madison, Wis. 53701

Froiland, S. G.
Dept. of Biology
Augustana College
Sioux Falls, S. Dakota 57102

Gasiorkiewicz, E.C.
U. Wis. - Parkside
Kenosha, Wis. 53140

Gennaro, Dr. A. L.
Natural History Museum
ENMU
Portales, New Mexico 88130

Germain, Mr. Clifford
Wis. Dept. Nat. Resources
Box 450
Madison, Wis. 53701

Goff, F. Glenn, Ecol. Sci. Div.
Atomic Energy Nat. Lab.
Oak Ridge, Tenn. 37830

Goodman, George J.
University of Oklahoma
770 Van Vleet Oval, Rm. 135
Norman, Okla. 73069

Graham, Benj. F.
Biol. Dept. - Grinnell College
Grinnell, Ia. 50112

Gray, Henry H.
Ind. Geol. Surv.
611 N. Walnut Grove
Bloomington, Ind. 47401

Gray, Richard W., Jr.
Dept. of Roads, P.O. Box 94759
Lincoln, Nebraska 68509

Grether, Dr. David
State College
St. Cloud, Minn. 56301

Grosklags, James H.
Biology Dept.
Northern Illinois University
DeKalb, Illinois 60115

Gustafson, Mr. and Mrs. Carl A.
Rt. 4, Box 63
Elkhorn, Wis. 53121

Gustafson, Mr. and Mrs. Roger D.
1037 N. Ottawa Ave.
Chicago, Ill. 60634

Hall, E. Raymond
Museum of Natural History
The University of Kansas
Lawrence, Kansas 66044

Hamerstrom, Drs. Frederic and Frances
R. 1
Plainfield, Wis.

Hammon, Joseph D. Jr.
3828 N. Ottawa Ave.
Chicago, Ill. 60634

Haney, Alan
Dept. of Botany
University of Illinois
Urbana, Ill. 61801

Hanson, Dr. George P.
Los Angeles State and County Arboretum
Arcadia, Calif. 91006

Hanson, Robert P.
5230 Dogwood Place
Madison, Wis. 53705

Harper, Kimball T.
Dept. of Botany
University of Utah
Salt Lake City, Utah

Harrison, Arthur L.
Harrison Associates, Inc.
Box 359
Nevada, Iowa 50201

Harrison, Darroll L.
Custer National Forest
P.O. Box 2556
Billings, Mont. 59103

Hartz, Mary K.
Muskegon Community College
Muskegon, Michigan 49442

Haskin, Larry
U. Wis. - Chemistry Dept.
Madison, Wis. 53706

Henderson, H.C., M.D.
9014 Leavenworth
Omaha, Neb. 68114

Henry, R.D.
Dept. of Biological Science
Western Illinois University
Macomb, Ill. 61455

Herbel, Carlton H.
ARS, USDA
Box 698
Las Cruces, New Mexico 88001

Hironaka, Dr. Min
Department of Botany
University of Idaho
Moscow, Idaho

Hoff, Mrs. Margaret
1312 Pocahantas Dr.
Madison, Wis. 53711

Hogan, William C.
35 Harmon Road
Scotia, N.Y. 12302

Holden, David J.
4801 Sheboygan Ave., Apt. 303
Madison, Wisconsin 53705

Hole, Dr. F.D.
203 Soils Bldg.
U. of Wis.
Madison, Wis. 53706

Holton, Carlyle
Oconomowoc High School
Oconomowoc, Wis. 53066

Holzbog, Dr. Charles
Asst. Prof. UW - Parkside
Kenosha, Wis. 53140

Huddleston, J. Herbert
College of Environmental Sciences
UW-Green Bay
Green Bay, Wis. 54302

Hulbert, Dr. Lloyd C.
Division of Biology
Kansas State Univ.
Manhattan, Kansas 66506

Hulett, Dr. G.K.
Dept. Biological Sciences
Fort Hays Kansas State College
Hays, Kansas 67601

Humke, John W.
708 Church St.
Evanston, Ill. 60201

Huntoon, James R.
Box 256
Monroe, Wis.

Huston, Scott
5322 Vicar Lane
Madison, Wis. 53716

Hutchinson, Mr. and Mrs. D.E.
5717 Baldwin Ave.
Lincoln, Nebraska 68500

Iltis, Dr. H.H.
U.W. Botany Dept.
Madison, Wis. 53706

Ingersoll, Mr. and Mrs. Bruce G.
743 Dearborn St.
Chicago, Ill. 60600

Isaac, Ronald
Dept. of Geography
Ohio University
Athens, Ohio

Jacobson, Walter A.
623 1/2 Wingra St.
Madison, Wis. 53700

Jensen, Paul
Biology Dept.
Carlton College
Northfield, Minn. 55057

Jensen, Peter
SRC of SCS
Room 604, 134 South 12th Street
Lincoln, Neb. 68508

Johnson, Albert G.
Dept. of Horticultural Science
University of Minnesota
St. Paul, Minn. 55101

Johnson, Donald Lee
Dept. of Geography
University of Illinois
Urbana, Ill.

Johnson, Marlin
Univ. of Wis. Waukesha Co. Campus
Waukesha, Wis. 53186

Jones, Michael
Nat. Lands Inst.
819 N. Main St.
Rockford, Ill. 61103

Jones, Mr. c/o Schramm
Knox College
Galesburg, Ill.

Jordan, William R. III
502 Valparaiso Road
Oak Ridge, Tenn 37830

Kannowski, Prof. Paul B.
Institute for Ecological Studies
U. of North Dakota
Grand Forks, N.D. 58201

Kehrberg, Ernest
Custer National Forest
P.O. Box 2556
Billings, Montana

Keith, Mrs. Betty
6631 Columbus Dr.
Middleton, Wis. 53562

Kelly, Robert H.
881 W. St. Charles Road
Lombard, Ill. 60148

Kersten, Dr. Herbert H.
1235 Fifth Ave., South
Fort Dodge, Iowa 50501

Kelsey, Mr. Lester
Route 5
Janesville, Wis. 53545

Kilburn, Dr. Paul
Principia College
Elsah, Illinois 62028

Kindschi, Dr. Donald
V.A. Hospital
Madison, Wisconsin 53705

King, Frank
Dept. of Natural Resources
Box 450
Madison, Wis. 53701

Kirsch, Leo
Woodworth Sta.
N. Prairie Wildlife Center
Woodworth, N.D. 58496

Kline, Mrs. Virginia
559 Chatham Terrace
Madison, Wisconsin

Knudsen, George J.
Chief Parks Naturalist
Dept. of Natural Resources
Box 450
Madison, Wis. 53701

Knutson, Roger M.
Luther College
Decorah, Iowa 52101

Koegel, Donald
Rm. 301 Courthouse
901 N. 9th St.
Milwaukee, Wis. 53233

Koelling, Alfred C.
Illinois State Museum
Springfield, Ill. 62700

Koeppen, Robert C.
USDA Forest Products Lab.
Walnut St.
Madison, Wisconsin

Kohlmeyer, Eugene M.
Box 528
Black River Falls, Wis. 54615

Komarek, E. V.
Tall Timbers Res. Sta.
Rt. 1 Box 110
Tallahassee, Fla. 32301

Korling, Dr. Torkel
Box 92
Dundee, Illinois 60118

Koser, Wayne S., Naturalist
Cranbrook Inst. of Sci. Nature Ctr.
500 Lone Pine Rd.
Bloomfield Hills, Mich. 48031

Krampert, Mr. Alfred P.
7754 7th Ave.
Kenosha, Wis. 53140

Kropp, David
Rt. 1
Plainfield, Ill. 60544

Kruse, Arnold D.
Arrowwood Refuge
Edmunds, N. Dakota 58434

Kruse, Harold G.
Hickory Hill Farm
Loganville, Wis.

Kucera, Dr. Clair L.
Department of Botany
Le Fevre Hall
University of Missouri
Columbia, Missouri 65201

Lace, Edward
R.R. 1, Box 90A
South Holland, Ill. 60473

Laing, Charles C.
Ohio Northern University
Basic Sciences Bldg.
Ada, Ohio 45810

Lamp, Herbert F.
Chairman, Biology Dept.
Northeastern Ill. State College
Bryn Mawr and St. Louis Ave.
Chicago, Ill. 60625

Lamping, Dr. John A.
DePaul U., 1036 W. Belden St.
Chicago, Ill. 60614

Landers, Dr. Roger Q.
Dept. Botany and Plant Phys.
Iowa State University
Ames, Iowa 50010

Lang, Jean Marie
4709 Jenewein Rd.
Madison, Wis. 53711

Lange, Kenneth I.
Devil's Lake State Park
Baraboo, Wis. 53913

Larsen, Andy
Riveredge Nature Center
Newburg, Wis. 53060

Lavigne, Robert
Box 3354, University Station
Laramie, Wyoming 82070

Lawrence, D. B.
2420 34th Ave., S.
Minneapolis, Minn. 55406

Ledingham, Geo. F.
Chmn., Biology Dept.
U of Sask.
Regina, Saskatchewan, Canada

Lemke, Dr. John
DePaw University
1036 W. Beldon Street
Chicago, Ill. 60614

Lemon, Dr. Paul C.
A.I.B.S.
3900 Wisconsin Avenue
Washington, D.C. 20016

Leopold, Stella
USGS
Denver, Colorado

Lester, J.E.
Department of Plant Science
University of Wyoming
Laramie, Wyoming

Levi, Dr. Herbert W.
Museum of Zoology
Harvard University
Cambridge, Mass.

Lewis, Philip, Jr.
Dept. of Landscape Architecture
University of Wis.
Madison, Wis. 53706

Lewis, Mr. Richard
Director, Cornell Plantations
Ithaca, New York 14850

Lindsey, Alton A.
Indiana Natural Areas Survey
Biology Department
Purdue University
Lafayette, Indiana

Loucks, Mr. Orie
U.W. Inst. Envt. Studies
Madison, Wis. 53706

Loyster, Earl
Department of Natural Resources
Box 450
Madison, Wis. 53701

Lukes, Mr. Roy
Ridges Sanctuary
Bailey's Harbor, Wis.

Lunn, Dr. Elizabeth T.
340 Flora Place
Highland Park, Ill. 60035

Lussenhop, John
U. of Wis. -Zoology
Madison, Wis. 53706

Lyon, Dr. David
Cornell College
Mt. Vernon, Ia. 52314

Maass, Mrs. Ann
5509 Tolman Terr.
Madison, Wis. 53711

Marshal, Paula
U.W. - Waukesha Co. Campus
Waukesha, Wis. 53186

Martin, Dr. S.G.
Dept. Zoology
Colorado State University
Ft. Collins, Colo.

McAleer, Dorothy
Kenosha, Wis. 53140

McCollum, E.H.
Horicon Natl. Wildlife Refuge
Mayville, Wis. 53050

McCollum, Homer
Rt. 1
Princeton, Minn. 55371

McFall, Donald
Nat. Land Institute
819 N. Main St.
Rockford, Ill. 61103

McIntosh, Dr. Robert
Biology Dept.
Notre Dame University
Notre Dame, Ind. 46556

McLane, Jack M.
1418 Washington
Burlington, Iowa 52601

McMillan, Professor Calvin
Botany Dept.
University of Texas
Austin, Texas 78712

Mc Millin, Fredrick N.
3310 Lake Mendota Drive
Madison, Wis. 53705

McPherson, James K.
Dept. of Botany
Oklahoma State University
Stillwater, Okla. 74074

McWilliams, Jesse
PMS
Soil Conservation Service Plant Center
Big Flats, N.Y.

Mehringer, Dr. Peter J.
Dept. of Anthropology
University of Utah
Salt Lake City, Utah 84112

Metcalfe
RFD1
Oregon, Illinois 61061

Meyer, Delbert
Dean, UW-Waukesha
Waukesha, Wis. 53186

Miller, Dr. E. J.
Dept. of Geography-Geology
Illinois State University
Normal, Ill. 61761

Miller, Mrs. Lotus
218 Parkridge Cir.
Ames, Ia. 50010

The Missouri Prairie Foundation
P.O. Box 200
Columbian, Missouri 65201

Moeller, Robert
1000 Aullwood Rd.
Dayton, Ohio 45414

Mohlenbrock, Robert
Dept. of Botany
Southern Illinois University
Carbondale, Ill.

Moir, Dr. W.H.
Dept. of Range Science
Colorado State University
Ft. Collins, Colo. 80521

Monk, Dr. and Mrs. David
Ed. Rsch and Envt. Science
University of Illinois
Urbana, Ill. 61801

Morgan, Dr. Michael
College of Environmental Sciences
UW-Green Bay
Green Bay, Wis.

Morley, Thomas
Botany Dept.
University of Minnesota
Minneapolis, Minn. 55455

Morrison, Darrel G.
Dept. Landscape Arch.
25 Ag Hall
U.W. - Madison
Madison, Wis. 53706

Moyer, J. Fred
Department of Biology
William Penn College
Oskaloosa, Iowa 52577

Neess, John
Department of Zoology
UW, Madison, Wis. 53706

Nelson, Mr. and Mrs. Chas.
Rt. 2, Box 215 K
Benton Harbor, Mich. 49022

Nelson, Senator Gaylord
U.S. Senate Offices
Washington, D.C. 20510

Nelson, Mr. and Mrs. James
1305 Glidden Rd.
Apt. 1116
DeKalb, Ill. 60115

Newell, Dr. L.C.
University of Nebraska
Lincoln, Neb. 68503

Newman, Robert
Extension and Horticulture Dept.
University of Wisconsin
Madison, Wis. 53706

Nichols, Stan
Botany Department
UW Extension
Madison, Wis. 53706

Nikolai, Charles P.
4-H and Youth Agent
Courthouse
Chilton, Wis. 53014

Nero, Robert
Museum of Man & Nature
Winnipeg, Manitoba, Canada

Norton, Dr. Don
Department of Botany and Plant Pathology
Iowa State University
Ames, Iowa 50010

Nyhoff, Mr. Joseph
Ill. Dept. of Conservation
Springfield, Ill. 62700

Ode, Mr. and Mrs. Arthur H.
2949 So. 97th St.
West Allis, Wis. 53227

Olmstead, Charles E.
Dept. of Biology
University of Chicago
1103 E. 57th St.
Chicago, Ill. 60637

Olsen, Ronald W.
Biol. Dept., Western Mich. U.
Kalamazoo, Mich. 49001

Olson, Paul
Chairman, Wis. Nature Conservancy
4122 Mineral Pt. Rd.
Madison, Wis. 53705

Otto, Mrs. Owen
9701 N. Prairie St.
Galesburg, Ill. 61401

Partch, Max
State Teachers College
St. Cloud, Minn. 56301

Pauly, Wayne
UW Arboretum
1207 Seminole Highway
Madison, Wis. 53707

Payton, Leland
410 S. Grand
Sedalia, Mo. 65301

Peet, R. K.
Ecology and Systematics Section
Cornell University
Ithaca, N.Y. 14850

Pellett, Mr. and Mrs. Franklin
Rt. 2
Newton, Iowa 50208

Petersen, LeRoy
914 Magnolia Lane
Madison, Wis. 53700

Peterson, Mary Lou
545 W. Dayton
Madison, Wis. 53715

Pohl, Dr. Richard
Department of Botany and Plant Pathology
Iowa State University
Ames, Iowa 50010

Popelka, Bernice P.
845 Silverbrook Drive
West Bend, Wis. 53095

Porter, Ivan R.
Soil Conservation Service, USDA
5401 Federal Office Building
Little Rock, Arkansas 72201

Potter, Dr. Loren D.
Dept. of Biology
University of New Mexico
Albuquerque, New Mexico 87106

Prager, Mr. and Mrs. Robert G.
Forest Park Nature Center
5809 Forest Park Dr.
Peoria, Ill. 61614

Pratt, LeRoy
317 S.W. 42nd
Des Moines, Iowa 50312

Purtell, Mrs. Charles Ed G., Jr.
7560 North River Road
Milwaukee, Wis. 53217

Rainwater, Miss Lisann
Principia College
Elsah, Ill. 62028

Ray, Dr. Burton W.
Department of Agronomy
N-415 Turner Hall
University of Illinois
Urbana, Ill. 61801

Read, Robert H.
4925 Elm St.
Downers Grove, Ill. 60515

Ready, Mrs. Audrey Ready
3002 Bluff St.
Madison, Wis. 53705

Reeves, Mr. John W.
Southern Ill. Univ. Outdoor Lab
Carbondale, Ill. 62901

Refuge Manager
Audubon Natl. Wildlife Refuge
Rt. 1
Coleharbor, N. Dakota 58531

Reich, Miss Binda
c/o U. of Wis. Arboretum
1207 Seminole Hwy.
Madison, Wis. 53711

Richards, Mary S.
c/o Dr. R.Q. Landers
Dept. of Botany
Iowa State University
Ames, Iowa 50010

Richards, Thomas M.
1237 N. Cass St.
Milwaukee, Wis.

Riechert, Susan
Dept. Zoology
Univ. of Wis., Madison, 53706

Riecken, F. F.
Dept. of Agronomy
Iowa State University
Ames, Iowa 50010

Risser, Dr. Paul
Botany Dept. - U. Oklahoma
Norman, Oklahoma 73069

Robinson, Mrs. Gladys C.
7920 S. Lafayette
Chicago, Ill. 60620

Rock, Mr. Harold W.
Naturalist, Milw. Co. Park Comm.
5879 So. 92nd St.
Hales Corners, Wis. 53130

Rose, Mr. and Mrs. David G.
2621 Boyce St.
Hastings, Neb. 68901

Rosenbrook, Donald
Wis. Natural Beauty Council
Dept. of Local Affairs and Development
Room 315, Brigham Hall
Platteville, Wis. 53818

Rouffa, Albert S.
Dept. of Biological Sciences
Univ. of Ill., Chicago Circle
Box 4348
Chicago, Ill. 60680

Russell, Ed, President
Doyle Dane Bernbach International
20 E. 43rd St.
New York, N.Y.

Rutherford, Mr. William L.
4801 Prospect Rd.
Peoria Heights, Ill. 61614

Ryan, Harold
SCS
916 East Ave.
Waukesha, Wis. 53186

Saiki, Mrs. Jeanne
628 Sprague St.
Madison, Wis. 53711

Salac, Sotero S.
Dept. of Hort. and Forestry
U. of Nebraska
Lincoln, Nebraska 68508

Salamun, Dr. Peter J.
UW-Milwaukee
Milwaukee, Wis. 53200

Sander, Mr. Phil
8026 7th Ave.
Kenosha, Wis. 53140

Salsbury Laboratories
Charles City,
Iowa 50616

Schaeffer, Alice
Scattergood School
West Branch, Iowa 52358

Schaefer, Margaret, Asst. Director
Stuhr Museum of the Prairie Pioneer
Box 636
Grand Island, Neb. 68801

Schaffer, Dr. J. C.
Associates for Tropical Biology
George Mason College
University of Virginia
Fairfax, Virginia 22030

Scharrer, Dr. Edward M.
6085 Brockway
Union Lake, Michigan

Schielzeth, Bruno
Route 1, Box 123
Union Grove, Wis. 53182

Schiffleger, Bruno, DDS
Rt. 1
Elkhorn, Wisconsin

Schluter, Beth
Waukesha County Parks
Waukesha, Wis.

Schmidt, Wm.
Ellsworth College
Iowa Falls, Iowa

Schramm, Dr. Peter
Biology Department
Knox College
Galesburg, Ill. 61401

Schroeder, Jim
GR City-County Bldg.
Madison, Wis. 53709

Schulenberg, Ray
Morton Arboretum
Lisle, Ill. 60532

Schwarzmeier, Jerry
W22085 Beeheim Rd.
Waukesha, Wis. 53186

Schwegman, John
Nat. Land Inst.
819 N. Main St.
Rockford, Ill. 61103

Scott, Walter
Dept. Natural Resources
Box 450
Madison, Wisconsin 53701

Scullin, Michael
Dept. of Sociology
Mankato State College
Mankato, Minn. 56001

Sengpiel, Heinz W.
State Highway Dept. - Capitol Grnds.
Bismarck, N.D. 58501

Severson, Mrs. Lu
6517 Elmwood
Middleton, Wis. 53562

Sexton, Dr.
Washington University
St. Louis, Mo.

Shepherd, Wm.
Dept. of Planning
Capital Hill Bldg.
5th Floor
Little Rock, Arkansas 72201

Shiflet, Thomas
Midwest RTSC, SCS
134 So. 12th St.
Lincoln, Nebraska 68508

Sill, Webster H., Jr.
Biology Dept. Univ. S. Dakota
Vermillion, S.D. 57069

Simonson, Clifford H.
Geography Dept.
Northern Ill. University
DeKalb, Ill. 60115

Simonson, Dr. Roy W.
Soil Conservation Service-USDA
Room 239
Federal Center Bldg.
Hyattsville, Maryland 20782

Slagle, A. Karl
Mo. Dept. of Cons. Bldg.
Bouchelle and Williams Sts.
Columbia, Mo. 65201

Smith, Dwight
Rt. 2
Dallas Center, Iowa

Smith, Galen
Dept of Biology, Wis. State U.
Whitewater, Wis. 53190

Smith, J.R.
1645 Park St.
Middleton, Wis. 53562

Smith, Leland
18 Courthouse
Kenosha, Wis. 53140

Smithberg, Margaret
Dept. of Hort. Sci.
U. of Minn.
St. Paul, Minn. 55101

Sorensen, Paul D.
Dept. of Biology
Northern Ill. University
DeKalb, Ill. 60115

Spencer, Larry T.
Biology Dept.-Boyd Hall
Plymouth State College
Plymouth, New Hampshire 03264

Springer, Mr. J. Tucker
Knox College c/o Peter Schramm
Galesburg, Ill. 61401

Staflet, Ada M.
19 Evans St.
Iowa City, Iowa 52240

Stearns, Dr. Forest
Biology Dept.
University of Wis. - Milw.
Milwaukee, Wis. 53200

Steinberg, Oliver
1509 Capital Ave.
Madison, Wis. 53705

Steliga, Kenneth, & Associates, Inc.
225 North Adams Street
Green Bay, Wis. 54301

Stephens, Thomas L.
64 Beth Mor Park
Bethalto, Ill.

Stephens, Tom
Dept. of Landscape Architecture
Southern Illinois University
Edwardsville, Ill.

Stephenson, Dr. Stephen N.
Department of Botany and Plant Pathology
Michigan State University
East Lansing, Michigan 48823

Stokes, M. A.
Lab. for Tree-Ring Research
University of Arizona
Tucson, Arizona 85721

Stone, Norman
Wis. Dept. of Natural Resources
Crest Meadows Wildlife Area
Grantsburg, Wis.

Strand, Paul M.
Sand Ridge Nature Center
RR 1, Box 90A
South Holland, Ill. 60473

Stuckey, Dr. Ronald L.
Carlton Herbarium
Ohio State University
Columbus, Ohio

Swan, F.R., Jr.
Biology Dept.
West Liberty State College
School of Natural Sciences
West Liberty, West Virginia 26074

Swink, Floyd
Morton Arboretum
Lisle, Ill.

Talbot, Dr. Lee M.
Smithsonian Institute
MNH-W323
Washington, D.C. 20560

Tans, Bill
DNR
Madison, Wis.

Taylor, Mrs. Allan
787 17th Street
Boulder, Colo. 80302

Ten Eyck, Tom
Dept. of Natural Resources
1845 Sherman Street
Denver, Colo. 80203

Terbilcox, Frank
Route 1
Baraboo, Wis. 53913

Thomas, John H.
Dept. of Biological Sciences
Stanford Sciences
Stanford, Calif. 94305

Thompson, Dr. Paul W.
17503 Kirkshire Rd.
Birmingham, Mich. 48009

Thomson, Mr. and Mrs. John
Rt. #1
Mt. Horeb, Wis. 53572

Thomson, Paul
1676 Rosada Dr.
St. Louis, Mo. 63183

Thorne, Robert F.
Rancho Santa Ana Botanic Garden
Claremont, Calif. 91711

Threlfall, Mrs. Maarit and Anna
5518 Barton Rd.
Madison, Wis. 53711

Tomanek, Dr. G.W.
Dept. Biological Sciences and Ag.
Fort Hays Kansas State College
Hays, Kansas 67601

Trigg, John
1000 Aullwood Rd.
Dayton, Ohio 45414

Troester, Herbert G.
Tewaukon National Wildlife Refuge
Cayuga, N.D. 58013

Trump, Richard
1511 13th St.
Ames, Iowa 50010

Tsao, Albert C.
U.W. Landscape Arch. - Ag Hall
Madison, Wis. 53706

Tucker, Richard
R.R. 2
Creston, Iowa 50801

Updike, Gerald
Necedah Refuge
Necedah, Wis. 54646

Vallier, Mr. & Mrs. Jacque D.
7817 North Club Circle
Milwaukee, Wisconsin 53217

Van Petten, Miss Aleeta
Knox College c/o Dr. Peter Schramm
Galesburg, Ill. 61401

Van Tuinen, Mr. and Mrs. Jacob
4521 S. Milky Way
Waukesha, Wis. 53186

Van Valkenburg, Charles
Southern Hills 129-12
Carbondale, Ill. 62901

Vocelka, Miss Sandra
c/o David Lyon
Cornell College
Mount Vernon, Iowa 52314

Vogl, Dr. Richard J.
Dept. of Botany
Calif. State College, L.A.
Los Angeles, Calif. 90032

Vognar, Alan
2563 W. 82nd Pl.
Chicago, Ill. 60652

Voight, John W.
General Studies Division
Southern Illinois University
Carbondale, Ill. 62901

Voss, Dr. Edward
Botany Department
University of Michigan
Ann Arbor, Mich.

Wade, Dr. and Mrs. Douglas
Route 2
Oregon, Ill. 61061

Wagner, Ben
4710 Mandrake Rd.
Madison, Wis. 53704

Wagner, John A.
Department of Science
Kendall College
Evanston, Ill. 60201

Wagner, Dr. Russel O.
Dept. of Biology
WSU - Platteville
Platteville, Wis. 53818

Ward, Dr. Richard T.
Biology Dept.
Colorado Stste University
Fort Collins, Colo.

Wali, Prof. Mohan
Inst. for Ecological Studies
U. of N. Dakota
Grand Forks, N.D. 58201

Webster, V. K.
Extension Leader
Box 218
Manchester, Iowa

Weise, Dr. Charles
UWM Zoology Dept.
Milwaukee, Wis.

Weller, Dr. Milton W.
Department of Zoology
Iowa State University
Ames, Iowa

Werner, Evelyn
Goose Pond Refuge
Rt. 1
Arlington, Wis.

Westcott, Chas.
Cook Co. Forest Preserve
Rt. 1, Box 334 Stover Rd.
Barrington, Ill. 60010

Westemeir, Ron,
Illinois Natural History Survey
Rt. 1
Effingham, Illinois

Whitaker, John O., Jr.
Dept. of Life Sciences
Indiana State University
Terre Haute, Indiana

White, Donald
Dept. of Hort. Sci.
U. of Minnesota
St. Paul, Minn. 55101

White, Keith
UW Center
Manitowoc, Wisconsin

White, Mr. & Mrs. Lester
R.R.2
Cherokee, Iowa

Whiteside, E. P.
101 Soil Science Bldg.
Michigan State University
East Lansing, Michigan 48823

Whitford, Dr. Phil P.
Botany Dept.
U. of Wis. - Milwaukee
Milwaukee, Wis. 53200

Whittaker, R.H.
Ecology & Systematics Section
Cornell University
Ithaca, N.Y. 14850

Wicklow, Donald
University of Wis. - Waukesha
Waukesha, Wis. 53186

Wilford, J.N.
New York Times
New York City, N.Y. 10000

Wilkinson, Prof. Denis R.
Dept. of Landscape Arch.
25 Ag Hall - U.W.
Madison, Wis. 53706

Willard, Dr. Beatrice E.
Thorne Ecological Foundation
1229 University Avenue
Boulder, Colo. 80302

Willard, Daniel
2217 W. Lawn Pl.
Madison, Wis. 53711

Williams, Tyler E., Jr.
3312 Prince William Drive
Fairfax, Virginia 22030

Wilson, Mr. Jim
Wilson Seed Farms
Polk, Nebraska 68654

Wilson, Dr. Roger E.
Department of Botany
Miami University
Oxford, Ohio 45056

Woehler, Gene
DNR
Fish Hatchery Drive
Madison, Wisconsin

Wolf, Susan
Dept. Zoology
Univ. of Wisconsin
Madison, Wis. 53706

Wormley, Jack
403 West 10th Street
Newton, Iowa

Wright, Mrs. Kenneth
1440 High
Boulder, Colorado 80302

Wright, Susan
Illinois Dept. Conservation
Springfield, Ill. 62700

Wuenscher, Mrs. Marcia
Rt. 2, Box 353
Guess Rd. Durham, N.C. 27705

Wyllie, Chancellor I.G.
UW - Parkside
Kenosha, Wis. 53140

Wynn, Ruth
Goose Pond Refuge
R. 1
Arlington, Wis.

Yambert, Dr. Paul
S.I.U. Outdoor Lab
Carbondale, Ill. 62901

Young, James
UW - Whitewater
Whitewater, Wisconsin

Youtz, W. H.
239 Wisconsin Ave., S.W.
Box 1357
Huron, South Dakota 57350

Yntema, Mr. and Mrs.
R. 1
Wadsworth, Illinois

Zedler, Dr. and Mrs. Paul
Dept. of Biology
San Diego State College
San Diego, Cal. 92115

Zimmerman, Dr. James H. & Elizabeth
2114 Van Hise Avenue
Madison, Wisconsin 53705

Huseth, Russell
R. 1, Rio, Wisconsin

Illinois Prairie Path
Box 5, Wayne, Ill. 60184

Herbert H. Hadow
Milton, Wisconsin 53563

Wilmer W. Steiner
Chief Plant Materials Specialist
Soil Conservation Service - USDA
Washington, D. C. 20250

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