Fifth Midwest Prairie Conference proceedings : Iowa State University, Ames, August 22-24, 1976. No. 5 1978

Ames, Iowa: Extension Courses & Conferences, Iowa State University, 1978

https://digital.library.wisc.edu/1711.dl/MISQTUDRJOGIB82

Proceedings
of the

FIFTH MIDWEST PRAIRIE CONFERENCE

August 22-24, 1976

Iowa State University
Ames, Iowa

Extension Courses & Conferences
102 Scheman Continuing Education Building
Iowa State University, Ames, Iowa 50011

Fifth Midwest

PRAIRIE CONFERENCE PROCEEDINGS

Iowa State University, Ames

August 22-24, 1976

Edited by

David C. Glenn-Lewin and Roger Q. Landers, Jr.
Department of Botany and Plant Pathology
Iowa State University

PREFACE

The setting in which the Fifth Midwest Prairie Conference was held retains little resemblance to its original wooded stream valley twisting through an endless prairie. The concrete, glass, carpet and manicured grass of the Scheman Continuing Education Building and ISU Center, however, did not inhibit the over 400 participants, whose enthusiasm for prairie things has grown with each conference. The traditions of the four previous conferences were maintained and strengthened, and continuity now extends through a decade, from the first conference in 1968 at Knox College to the upcoming sixth at the Fawcett Center for Tomorrow, The Ohio State University, Columbus, August 13-16, 1978.

The diversity of backgrounds of the participants mirrors the diversity of the original prairie. It was also evident in the content of the papers as we began to assemble the Proceedings. With a few exceptions, all papers were reviewed by someone in additional to Glenn-Lewin and Landers, not on an acceptance-rejection basis, but as a source of constructive opinion to help authors improve their articles. We have assembled the papers into the three broad groups: Ecological Studies, Restoration and Management, and History, Politics and Education, but we realize there is considerable overlap. Many articles were presented by first-time authors, which is encouraging. These, as well as the ones by old-timers, are greatly appreciated.

The committee which helped put the conference together was composed of prairie enthusiasts throughout Iowa. At a critical stage of planning one of its members, George Aurand, provided a gift which gave us confidence to proceed vigorously. The enthusiasm and talents of the committee produced "A Guide to Some Iowa Prairies", which was available to participants who registered early. Attempts to initiate a complete natural area survey of the state have, in part, grown out of this guide.

The committee carried out its responsibilities well, but behind the scenes, it was the staff of the Scheman Continuing Education Building and the Brunnier Gallery that made the conference go from the beginning.

The sketches of prairie plants which have appeared in the announcements, conference program, and finally in the Proceedings were done by Carol Peck, graduate student in Botany and Plant Pathology, Iowa State University.

Final typing of the articles was done by Carla Holbrook and Jill Smart.

We are greatly indebted to the many people who helped the conference and Proceedings through to the finish. However, the greatest debt we owe is to the prairie itself, which in its destruction, provided the economy by which we have been sheltered, clothed, fed, education and entertained.

David C. Glenn-Lewin and Roger Q. Landers, Jr.

Ames, Iowa 1978

REVIEWERS OF MANUSCRIPTS

Roger Anderson
L. Best
J. Brotherson
G. Clambey
R. Dahlgren
C. Davis
H. Dolling
L. Eilers
D. Farrar
L. Frederick
D. Hockett
H. Kantrud
C. Kucera
C. LaMotte
Herbert Lamp
B. Menzel
R. K. Peet
R. Pohl
W. Scholtes
P. Schramm
J. Sinatra
Daryl Smith
D. Staniforth
A. van der Valk

TABLE OF CONTENTS

TABLE OF CONTENTS CONTINUED

ECOLOGICAL STUDIES

By its very nature, the science of ecology exhibits a diversity of approaches and subjects, and the papers included in this section illustrate this diversity. Of several possible ways to organize the papers on ecological studies, we chose to put the historical and geographical papers first, vegetation papers next, and then those dealing with populations and plant-animal interactions.

The papers by Baker and Van Zant, Moran, and Schroeder are reconstructions of presettlement vegetation, in northwest Iowa, northeast Illinois, and Missouri, respectively. Betz provides an overview of the prairies of Indiana. Three articles, those by Clambey and Landers on Iowa wetlands, Landers on prairies in national parks, and Wilson on prairies of Waukesha County, Wisconsin, are geographical descriptions of prairie vegetation.

Several articles concern vegetation structure, vegetation dynamics, or vegetation-environment relationships. Included in this subsection are the papers by Brotherson and Landers on natural revegetation following grazing; Crist and Glenn-Lewin on the structure of a prairie coenocline; Currier, Davis and van der Valk on Eagle Lake marsh, Iowa; Herman and Kucera on soil micro-biomass; Johnson, Oksanen and Finney on the beta attenuation method of measuring structure and production; and Rieken and Tembhare on soil phosphorus and potassium.

Following these are four papers concerned with plant populations. Dokken and Hulbert examined fire, standing dead and density of <u>Andropogon gerardii</u>; Grether studied population differences in <u>Maianthemum canadense</u>; Hermann-Parker analyzed the life-history of <u>Psoralea esculenta</u>; and Holden, Chen and Ellis have done cloning of prairie plants by tissue culture.

One animal population paper, on the massasauga (<u>Sistrurus catenatus</u>), is by Bushey.

Plant and animal interactions are the subjects of the last three papers in this section. These are by George, on prairie as gamebird habitat; Probasco, on bird populations in Missouri glades; and Edwards, on the possible role of bison in the prairie ecosystem.

THE HISTORY OF PRAIRIE IN NORTHWEST IOWA: THE POLLEN AND PLANT MACROFOSSIL RECORD

Richard G. Baker
Department of Geology
University of Iowa
Iowa City, Iowa 52242

and

Kent L. VanZant
Department of Geology
Beloit College
Beloit, Wisconsin 53511

ABSTRACT

Prairies are geologically recent features of Iowa's landscape. A core from Lake West Okoboji indicates that prairie plants arrived about 9000 years ago. Macrofossils of *Amorpha canescens*, *Verbena stricta*, and other prairie indicators, and pollen of *Amorpha* and *Petalostemum* appeared about that time, accompanied by increasing percentages of Gramineae, *Artemisia*, and other Compositae pollen. *Quercus* and *Ulmus* pollen percentages declined at that time. Pollen of prairie taxa, plus charred seeds and leaves, persisted until European settlers arrived. These fossils indicate that prairie was present and fires were common. Sediments suggest that lake level was lower about 6000 years ago.

INTRODUCTION

The history of Iowa's prairie flora is obscure. Records are not available for the earliest prairie development, which was presumably in the Tertiary; no Tertiary rocks are exposed in Iowa. During the Quaternary, repeated glaciations destroyed the prairie. Sediments that might record these events are mostly lacking, although a site in Crawford County, Iowa, is an exception. Lane's (1941) palynological analysis indicates that an interglacial prairie developed at that site. Data are available only from deposits of the last 30,000 years, and these data suggest that *Picea*-*Pinus* forests prevailed until about 22,000 years ago (Lane 1941; Baker, unpublished data). *Pinus* was then eliminated, and *Picea*-*Larix* forests were present until about 11,000 years ago (Baker, unpublished data; VanZant 1976, Hall 1971).

Pollen from several bogs in central Iowa (Fig. 1; Lane 1931, Brush 1967, Durkee 1971) and adjacent areas (Wright et al. 1963) indicate that deciduous forest gave way to prairie in early post-glacial time. Details of Iowa's prairie development are poorly known. This paper summarizes prairie development in northwestern Iowa based on pollen and macrofossils (preserved seeds, leaves, and fruits) or prairie plants found in lake sediments.

METHODS

Lake West Okoboji, Dickinson County, Iowa (Fig. 1), was cored with a Livingstone piston corer in March 1975. The core was sampled for pollen at 10 cm. intervals, and the samples were processed following Faegri and Iversen (1964). Pollen was identified using keys in Faegri and Iversen (1964), Kapp (1969), and McAndrews et al. (1973), and by comparison to the pollen reference collection of the University of Iowa. At least 300 grains of arboreal and non-arboreal anemophilous pollen were counted from each sample.

Lengths of core 10 cm. long were sieved through 500 and 125 micron mesh screens to concentrate plant macrofossils, which were picked from the residues. These fossils were identified by comparison to the reference collection of the Department of Geology and the Herbarium of the University of Iowa. Pictures in Martin and Barkley (1961), Beijerinck (1947), and Katz and Kipiani (1965) were also used for comparisons.

Several samples of the core were submitted for radiocarbon-dating. These dates are plotted in Figure 2.

RESULTS

Ulmus and *Quercus* pollen percentages declined rapidly at approximately 9000 RCYBP (radiocarbon years before the present, Fig. 2). Their decline and the increase in Gramineae, *Artemisia*, and *Ambrosia* pollen mark the base of the Gramineae-*Artemisia*-*Ambrosia* pollen assemblage zone. Chenopodiaceae-Amaranthaceae and Compositae pollen also increased at approximately the same time (Fig. 2). Pollen of *Amorpha* and *Petalostemum* first occur near the base of this zone and continue upward in small but nearly consistent percentages. These genera are largely insect pollinated, and therefore, their pollen grains are not as likely to be deposited in lake sediments as are grains of those plants whose pollen is wind-disseminated.

Macrofossils of prairie plants first occurred within the Gramineae-*Artemisia*-*Ambrosia* pollen assemblage zone. Pods of *Amorpha canescens* were the most abundant (Fig. 2). The first occurrences of *Amorpha canescens* pods and *Amorpha* pollen grains are approximately synchronous. *Chenopodium* spp., particularly *C. album*, seeds appeared and increased in abundance during this zone. Some macrofossils were charred as if burned. Similar charred fossils were found in overlying zones.

The Gramineae-*Ambrosia* pollen assemblage zone is characterized by low percentages of *Quercus* and *Ulmus* pollen (less than 10%), abundant but erratic percentages of Gramineae (to 39%), *Ambrosia* (to 58%) and Chenopodiaceae-Amaranthaceae (to 18%) pollen, a slight increase in Compositae pollen, a decrease in *Artemisia* pollen (to generally less than 10%), and the continued periodic occurrences of *Amorpha* and *Petalostemum* pollen (Fig. 2).

Amorpha canescens pods and leaves increased in abundance in this zone (Fig. 2). Seeds of *Verbena stricta* and *Helianthus* cf. *laetiflorus*, two other indicators of prairie vegetation, were also found in this zone. Seeds of *Chenopodium* spp., particularly *C. album* and *C. rubrum*, increased in abundance in this zone. Seeds of *Zannichellia palustris*, a shallow-water aquatic, increased while those of *Najas flexilis*, an aquatic that often grows in deeper water, declined (Fig. 2). This zone is dated at approximately 7730 to 3240 RCYBP.

The Quercus-NAP (nonarboreal pollen) assemblage zone is characterized by an increase in Quercus (to 20%), or lower, more consistent percentages of Gramineae, Ambrosia, and Chenopodiaceae-Amaranthaceae pollen (Fig. 2). Amorpha and Petalostemum pollen grains were frequently present, and Compositae was consistently present although in smaller percentages than in the Gramineae-Ambrosia pollen assemblage zone (Fig. 2). The Quercus-NAP assemblage zone is dated from approximately 3200 RCYBP to 1865 AD. Few macrofossils were present in this zone. A few seeds of the aquatic plants, Najas flexilis and Zannichellia palustris, and an occasional seed of upland and weedy species are all that were present. Amorpha leaves were found in nearly every sample.

The Ambrosia pollen assemblage zone dates from approximately 1865 to the present, the period of settlement by Europeans in Dickinson County. The zone is characterized by an increase in Ulmus pollen, a striking increase in Ambrosia pollen (to 60%), an increase in Chenopodiaceae-Amaranthaceae (to 14%), and decreases in Gramineae, Artemisia, and Compositae pollen. Pollen of Amorpha and Petalostemum were less abundant during this zone. Pods and leaves of Amorpha canescens were present during the earlier portions of this zone.

DISCUSSION

The decrease in Quercus and Ulmus pollen and the rise in NAP at approximately 9000 RCYBP mark the decline of deciduous forest in northwestern Iowa. Open areas on the upland were occupied by prairie taxa, such as Amorpha canescens, Petalostemum, Verbena stricta, and Compositae. Other herbs, such as Chenopodium spp., Ambrosia, and Artemisia, also increased in abundance. Some of the weedy species, such as Ambrosia artemisiifolia and Chenopodium album, probably grew in disturbed areas.

The prairie vegetation became more dominant between 9075 ± 90 and 7730 ± 80 RCYBP. Trees declined in abundance and were increasingly localized in protected areas around the lake. The charred macrofossils suggest that the decline of the deciduous forest was abetted by periodic fires. The decrease in the number of Najas flexilis and the increase in the abundance of Zannichellia palustris seeds in the upper part of this zone suggest that the lake became shallower during this time period. The climate was apparently drier.

The erratic fluctuations in the pollen percentages of Gramineae, Ambrosia, and Chenopodiaceae-Amaranthaceae between 7730 ± 80 and 3240 ± 65 RCYBP probably reflect fluctuations in lake level which alternately created, then destroyed sites for these plants. Amorpha canescens, Verbena stricta, Helianthus cf. laetiflorus, and Petalostemum, all of which are abundant during this time period, probably occupied stable upland sites. Large mudflats were exposed during droughts, and were colonized by Chenopodium album, C. rubrum, Ambrosia artemisiifolia, and A. psilostachya, and also Euphorbia maculata, E. preslii, Rumex maritimus var. fueginus, Polygonum lapathifolium, Cyperus odoratus, and C. strigosus. This interval represents the warmest and driest part of postglacial time.

Quercus became more abundant after 3240 ± 65 RCYBP. Moisture was apparently more plentiful; these trees occupied moist ravines and low-lying areas around the lake and along the Little Sioux River. Ulmus trees increased in abundance too, but not to the same extent as Quercus. Some other aboreal taxa which produce lesser amounts of pollen, such as Tilia, Acer saccharinum, Carya, Ostrya-Carpinus, Juglans cinerea, J. nigra, and Fraxinus pennsylvanica-type, also increased in abundance or returned to the areas after an absence of several thousand years. Prairie occupied the uplands and most of the slopes. Sedimentological and plant macrofossil evidence suggests that the lake level rose.

After approximately 1965, European settlers immigrated into Dickinson County. The county's population increased from 121 people in 1859 to 1389 in 1870 (Hull 1883). Many acres of prairie sod were plowed for agricultural purposes. Weeds, such as Ambrosia and Chenopodium, and Ulmus seedlings, increased in abundance while prairie taxa such as some Compositae, Petalostemum, and Amorpha canescens, decreased. Prairie fires decreased in frequence, and eventually ceased.

This outlined vegetational sequence fits fairly well with environmental reconstructions for central Iowa based primarily on detailed studies of soil and bog stratigraphy (Walker 1966).

LITERATURE CITED

Beijerinck, Willem. 1947. Zadenatlas Der Nederlandische Flora. H. Veenman and Zoen, Wageningen. 316 p.

Brush, Grace S. 1967. Pollen analyses of late-glacial and postglacial sediments in Iowa. In: Cushing, E. J. and H. E. Wright, Jr., Eds. Quarternary Paleoecology. Yale Univ. Press, New Haven. pp. 99-115.

Dulian, James J. 1975. Paleoecology of the Brayton local biota, Late Wisconsinan of southwestern Iowa. M.S. thesis. Univ. Iowa, Iowa City. 50 p.

Durkee, L. H. 1971. A pollen profile from Wodon Bog in northcentral Iowa. Ecology 52:837-844.

Faegri, Knut, and Johs Iversen. 1964. Textbook of pollen analysis. Munksgaard, Copenhagen. 237 p.

Hall, Stephen A. 1971. Paleoecological interpretation of Bison, mollusks, and pollen from the Hughes peat bed, Linn County, Iowa. M.S. thesis. Univ. Iowa, Iowa City. 75 p.

Hull, John A. 1883. Census of Iowa for 1880. State of Iowa, Des Moines. 744 p.

Kapp, R. O. 1969. How to know pollen and spores. Wm. C. Brown Co., Dubuque. 249 p.

Katz, N. Ja., and M. G. Kipiani. 1965. Atlas and keys of fruits and seeds occurring in the Quaternary deposits of the U.S.S.R. Nauka, Moscow. 365 p. (in Russian)

Kramer, Thomas L. 1972. The Paleoecology of the postglacial Mud Creek Biota, Cedar and Scott Counties, Iowa. M.S. thesis. Univ. Iowa, Iowa City. 69 p.

Lane, George H. 1931. A preliminary pollen analysis of the East McCulloch peat bed. Ohio J. Sci. 31:165-171.

Lane, George H. 1941. Pollen analysis of interglacial peats of Iowa. Iowa Geol. Sur. Ann. Rept. 37:233-262.

Martin, A. C., and W. D. Barkley. 1961. Seed identification manual. Univ. Calif. Press, Berkeley. 221 p.

McAndrews, J. H., A. A. Berti, and G. Norris. 1973. Key to the Quaternary pollen and spores of the Great Lakes region. Royal Ont. Mus. Life Sci. Misc. Publ. 61 p.

Szabo, John P. 1975. The Quaternary history of the lower part of Pioneer Creek basin, Cedar and Jones counties, Iowa. Ph.D. thesis. Univ. Iowa, Iowa City. 173 p.

VanZant, Kent L. 1976. Late- and postglacial vegetational history of northern Iowa. Ph.D. thesis. Univ. Iowa, Iowa City. 123 p.

Walker, P. H. 1966. Postglacial environments in relation to landscape and soils on the Cary drift, Iowa. Iowa St. Univ. Ag. Home Econ. Expt. Stat. Res. Bull. 549. pp. 838-875.

Webb, Thompson, III. 1973. Pre- and post-settlement pollen from a short core, Blackhawk Lake, west-central Iowa. Proc. Iowa Acad Sci. 80:41-44.

Wright, H. E., Jr., T. C. Winter, and H. L. Patten. 1963. Two pollen diagrams from southeastern Minnesota: Problems in the regional late-glacial and postglacial vegetational history. Bull. Geol. Soc. Amer. 74:1371-1396.

Figure I.

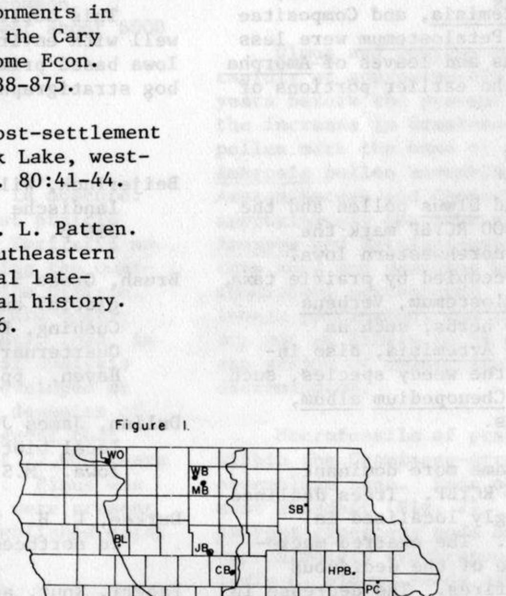


Fig. 1. A map of Iowa showing the sites of previous studies and the extent of Lake Wisconsinan glacier ice. LWO = Lake West Okoboji (this report); SB = Sumner Bog (VanZant, 1976); BQ = Brayton Quarry (Dilian, 1975); BL = Blackhawk Lake (Webb, 1973); WB = Woden Bog (Durkee, 1971); MB = McCulloch Bog (Brush, 1967, Lane, 1931); JB = Jewell Bog (Brush, 1967); CB = Colo Bog (Brush, 1967); HPB = Hughes Peat Bed (Hall, 1971); PC = Pioneer Creek (Szabo, 1975); MC = Mud Creek (Kramer, 1972). Larger dots = complete sections.

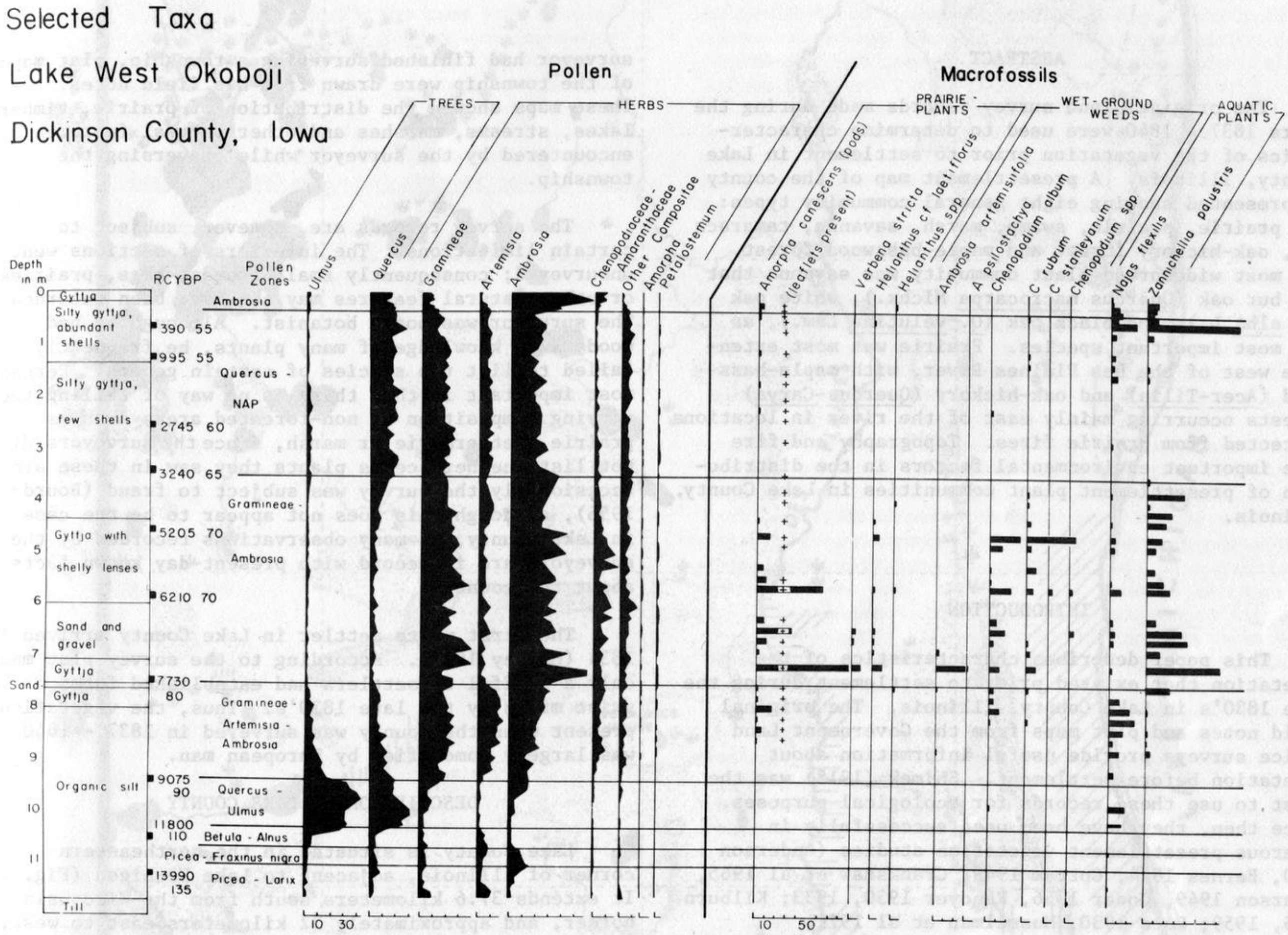


Fig. 2. Selected taxa of pollen and macrofossils, Lake West Okoboji, Iowa. Numbers under the pollen curves are percentages. Numbers under the macrofossils are numbers of fossils per 5 cm. of core (diameter ca. 5 cm.)

PRESETTLEMENT VEGETATION OF LAKE COUNTY, ILLINOIS

Robbin C. Moran

117 West Blodgett Avenue
Lake Bluff, Illinois 60044

ABSTRACT

The original land survey records made during the years 1837 - 1840 were used to determine characteristics of the vegetation prior to settlement in Lake County, Illinois. A presettlement map of the county is presented showing eight general community types: wet prairie, prairie, swamp, marsh, savanna, tamarack bog, oak-hickory forest and maple-basswood forest. The most widespread plant community was savanna that had bur oak (*Quercus macrocarpa* Michx.), white oak (*Q. alba* L.), and black oak (*Q. velutina* Lam.), as the most important species. Prairie was most extensive west of the Des Plaines River, with maple-basswood (*Acer*-*Tilia*) and oak-hickory (*Quercus*-*Carya*) forests occurring mainly east of the river in locations protected from prairie fires. Topography and fire were important environmental factors in the distribution of presettlement plant communities in Lake County, Illinois.

INTRODUCTION

This paper describes characteristics of the vegetation that existed prior to settlement during the late 1830's in Lake County, Illinois. The original field notes and plat maps from the Government Land Office surveys provide useful information about vegetation before settlement. Shimek (1915) was the first to use these records for ecological purposes. Since then, they have been used successfully in numerous presettlement vegetation studies (Anderson 1970, Barnes 1974, Cottam 1949, Crankshaw et al 1965, Ellarson 1949, Goder 1956, Kenoyer 1930, 1933; Kilburn 1955, 1959; Lutz 1930, Musselman et al 1971, Neuenschwander 1956, Potzger and Potzger 1950, Stroessner et al 1966, Tans 1976, Ward 1956a, 1956b; Wuenscher and Valiunas 1967). Methods used by the early surveyors, and their implications for vegetation analysis from the survey records, have been discussed by Bourdo (1956). He concluded that the survey records, when used in conjunction with other non-survey sources of information, provide a good picture of vegetation as it existed prior to settlement. Curtis (1959) states that surveyors' records remain the best source of information available on the nature of Wisconsin's vegetation before European settlement.

Essentially, the surveyor's job was to establish a grid system of township and section lines so that future homesteads could be easily located. To do this, corner points were established along the section lines at every half mile (0.8 km; the quarter section corner) and mile (1.6 km; the interior section corner). If an area was prairie or marsh, a post was set in the ground. If forested areas, the nearest durable and sizeable tree in each section (the "Witness" or "Bearing" tree) was blazed, and the distance and direction of the tree from the corner, the species of tree and its diameter at breast height (DBH) were recorded. At quarter section corners only two trees were blazed. Finally, at the end of each mile, the surveyor was required to describe the predominant vegetation encountered over that mile. After a surveyor had finished surveying a township, plat maps of the township were drawn from his field notes. These maps showed the distribution of prairie, timber, lakes, streams, marshes and other natural features encountered by the surveyor while traversing the township.

The survey records are, however, subject to certain limitations. The interiors of sections went unsurveyed; consequently small groves, bogs, prairies or other natural features may not have been recorded. The surveyor was not a botanist. Although he had a woodsman's knowledge of many plants, he frequently failed to list the species of certain genera. Perhaps most important is that there is no way of telling the varying composition of non-forested areas such as prairie, wet prairie or marsh, since the surveyors did not list the herbaceous plants they saw in these areas. Occasionally the survey was subject to fraud (Bourdo 1956), although this does not appear to be the case in Lake County, as many observations recorded by the surveyors are in accord with present-day known facts about the county.

The first white settler in Lake County arrived in 1834 (Halsey 1912). According to the survey plat maps, only a handful of settlers had established farms or grist mills by the late 1830's. Thus, the vegetation present when the county was surveyed in 1837 - 1840, was largely unmodified by European man.

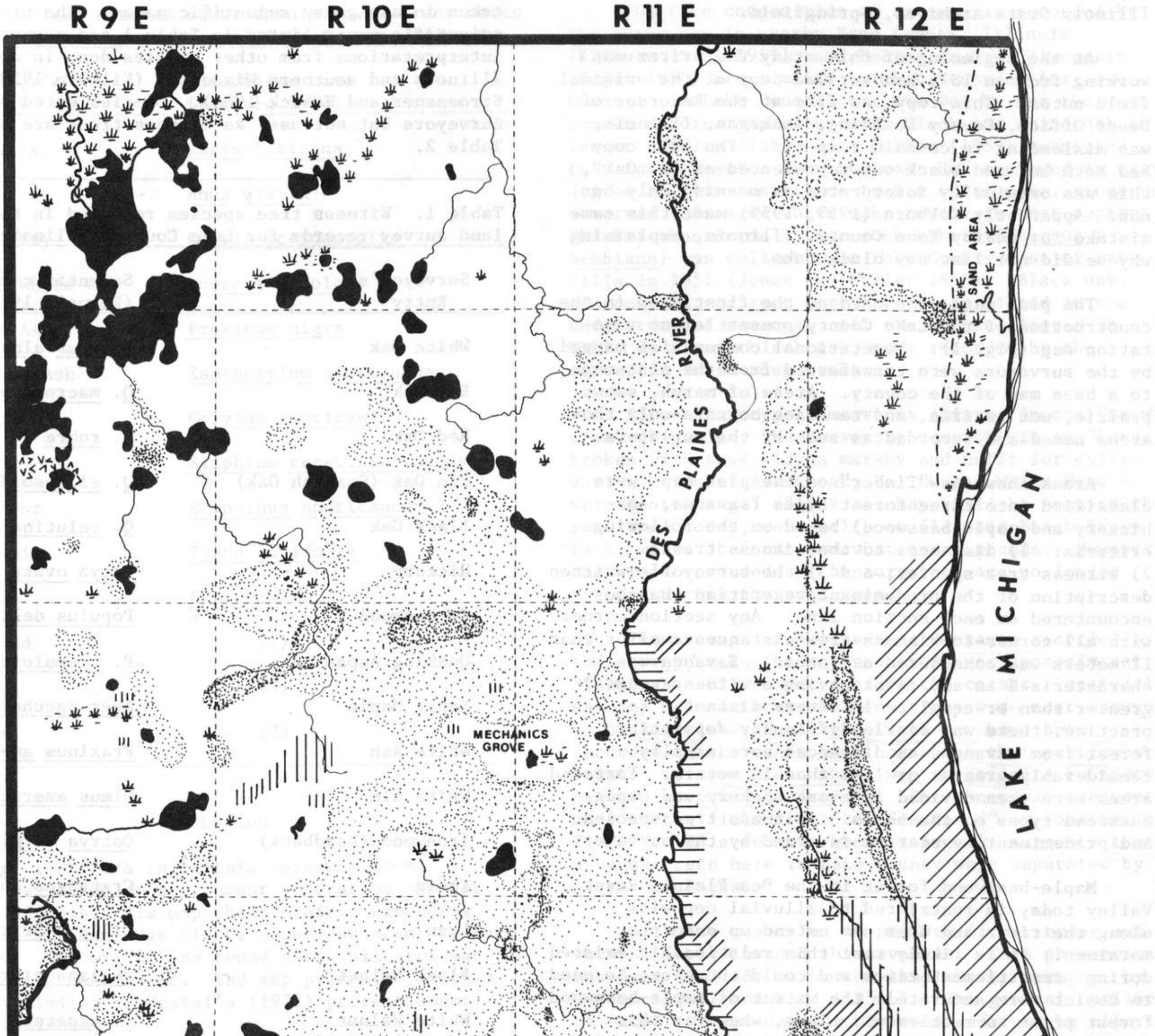
DESCRIPTION OF LAKE COUNTY

Lake County is situated in the northeastern corner of Illinois, adjacent to Lake Michigan (Fig. 1). It extends 37.6 kilometers south from the Wisconsin border, and approximately 32 kilometers east to west, covering an area of 1183 square kilometers. Topography in Lake County is characteristic of the Wheaton morainal country - level to gently rolling hills - with the prominent Lake Border Morainic System extending north and south between Lake Michigan and the Des Plaines River, and the Valparaiso Morainic System paralleling to the west (Willman 1971). The eastern halves of the two northernmost townships adjacent to Lake Michigan in Range 12 (Fig. 1) are distinct from the rest of the county. This tract of land is covered by extensive sand deposits that were formed by glaical Lake Chicago.

Drainage in the county is poor, with many streams or drainageways ending in depressions or marshes. A strip of land 3.2 to 4.8 kilometers wide along the eastern edge of the county drains into Lake Michigan. The Des Plaines River, which runs north-south through Range 11 (Fig. 1), drains approximately one-half of the county. The western portion of the county is drained by the Fox River.

METHODS

Microfilms of the original survey data were examined at the University of Wisconsin Archaeological Research Laboratory, Milwaukee, Wisconsin. The Lake County Forest Preserve District in Libertyville, Illinois, provided photostat copies of the original township plat maps. The original survey notes and pla



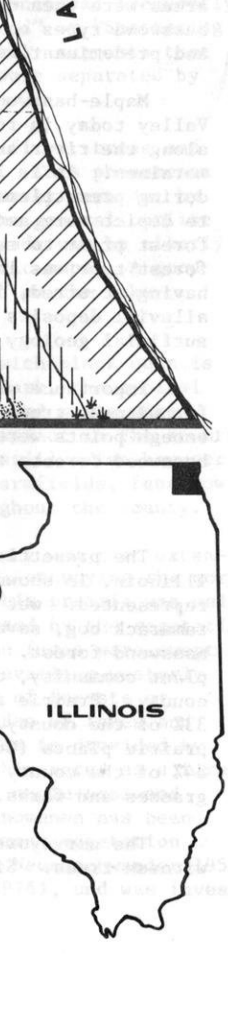
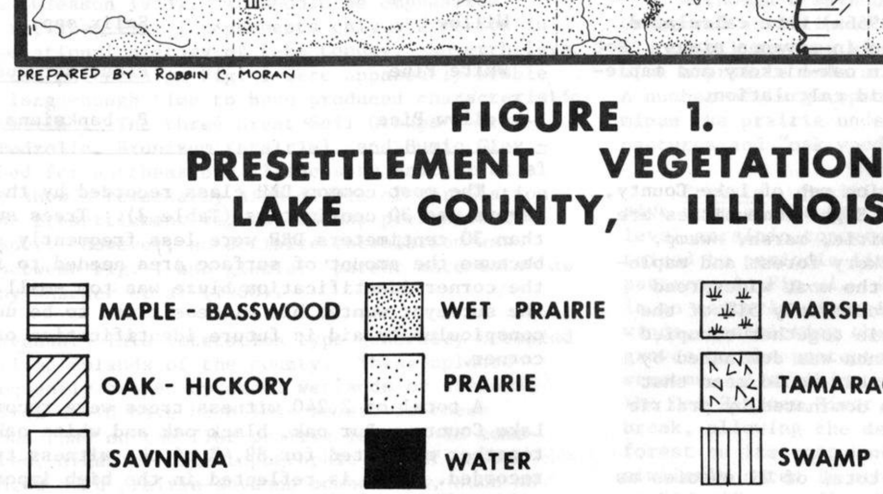


FIGURE 1.
PRESETTLEMENT VEGETATION OF LAKE COUNTY, ILLINOIS



maps for all Illinois counties are preserved at the Illinois State Archives, Springfield.

At the beginning of this study the writer was working from an 1871 handscribed copy of the original field notes. This copy, on file at the Recorder of Deeds Office, County Building, Waukegan, Illinois, was misleading in certain respects. The 1871 copy had both bur and black oak represented as "B. Oak", this was originally interpreted as meaning only bur oak. Apparently Kilburn (1955, 1959) made this same mistake for nearby Kane County, Illinois, explaining why he did not list any black oaks.

The plat maps were used as the first step in the construction of the Lake County presettlement vegetation map (Fig. 1). Vegetational communities mapped by the surveyors were transferred from the plat maps to a base map of the county. Areas of marsh, swamp, prairie, wet prairie, and tamarack bog are only those areas named and recorded as such by the surveyors.

Areas shown as "Timber" on the plat maps were classified into three forest types (savanna, oak-hickory and maple-basswood) based on the following criteria: 1) distances to the witness trees; 2) witness tree species; and 3) the surveyor's written description of the predominant vegetation that he encountered on each section line. Any section corner with all corner-to-witness-tree distances smaller than 12 meters was considered as forest. Savanna was characterized as any point having a witness tree(s) greater than or equal to 12 meters distant. In practice, there was little difficulty separating forest from savanna, as distances were usually considerably greater or less than 12 meters. Forested areas were then divided into oak-hickory and maple-basswood types on the basis of witness tree species and predominant vegetation recorded by the surveyor.

Maple-basswood forest in the Des Plaines River Valley today is restricted to alluvial deposits along the river and does not extend up onto the moraines. It is likely that this relationship existed during presettlement times and could therefore be used to depict more accurately the extent of maple-basswood forest prior to settlement. Thus, wherever this forest type was interpreted from the survey records as having occurred, it was mapped in conjunction with alluvial deposits as shown by Willman (1971) in his surficial geology map of the Chicago region.

Importance values (Ward 1956a) were calculated for witness trees that occurred in savanna areas. Not enough points were available in oak-hickory and maple-basswood forests to make a valid calculation.

RESULTS

The presettlement vegetation map of Lake County, Illinois, is shown in Fig. 1. Eight communities are represented: wet prairie, prairie, marsh, swamp, tamarack bog, savanna, oak-hickory forest and maple-basswood forest. Savanna was the most widespread plant community, covering approximately 51% of the county. Prairie and wet prairie together occupied 33% of the county. Since savanna was dominated by prairie plants (Curtis 1959), this would mean that 84% of the county was actually dominated by prairie grasses and forbs.

The surveyors recorded a total of 21 species as witness trees. Since only the common names of the witness trees were listed by the surveyor, care was taken in assigning scientific names. The probable scientific names listed in Table 1 are supported by interpretations from other studies done in northeastern Illinois and southern Wisconsin (Kilburn 1959, Stroessner and Habeck 1966). Species noted by the surveyors but not used as witness trees are shown in Table 2.

Table 1. Witness tree species recorded in the original land survey records for Lake County, Illinois.

Surveyor's Entry	Scientific name (Fernald 1950)
White Oak	Quercus alba
Bur Oak	Q. macrocarpa
Red Oak	Q. rubra
Pin Oak (Spanish Oak)	Q. ellipsoidalis
Black Oak	Q. velutina
Hickory	Carya ovata
Cottonwood	Populus deltoides
Quaking Aspen	P. tremuloides
Sugar Maple	Acer saccharum
White Ash	Fraxinus americana
White Elm	Ulmus americana
Ironwood (Hardback)	Ostrya virginiana
Thorn	Crataegus spp.
Lynn	Tilia americana
Black Walnut	Juglans nigra
White Walnut	J. cinerea
Birch	Betula papyrifera
Cherry	Prunus serotina
Willow	Salix spp.
White Pine	Pinus strobus
Yellow Pine	P. banksiana

The most common DBH class recorded by the surveyors was 30 centimeters (Table 3). Trees smaller than 30 centimeters DBH were less frequently selected because the amount of surface area needed to inscribe the corner identification blaze was too small. Also, the surveyor wanted his witness trees to be durable and conspiculus to aid in future identification of the corner.

A total of 2,240 witness trees were recorded in Lake County. Bur oak, black oak and white oak together accounted for 89.6% of the witness trees recorded. This is reflected in the high importance values (Table 4) for these species.

Table 2. Plant species other than witness trees noted by the early land surveyors in Lake County, Illinois.

Surveyor's Entry	Scientific name (Fernald 1950)
Tamarack	Larix laricina
Sumac	Rhus glabra
Hackberry	Celtis occidentalis
Swamp White Oak	Quercus bicolor
Black Ash	Fraxinus nigra
Prickly Ash	Zanthoxylum americanum
Hazel	Corylus americana
Rosin	Silphium terebinthinaceum
Red Root	Ceanothus americanus
Cat Tail	Typha latifolia
Indigo	Baptisia sp.
Red Bud	(?)
Briar	(?)
Vines	(?)

DISCUSSION

Fig. 1 differs in certain respects from Anderson's (1970) presettlement vegetation map for all of Illinois. His map shows prairie extending along the eastern edge of the county adjacent to Lake Michigan. The writer has found that this area was dominated by oak forest. The map presented in this paper is similar to Vestal's (1931) presettlement map of Illinois.

In post-glacial time the composition and distribution of vegetation in the Midwest has undergone major changes in response to varying climatic conditions (Gleason 1923). It should be emphasized therefore, that Fig. 1 represents only one period in the vegetational history of Lake County. Nevertheless, vegetation patterns in Fig. 1 were apparently stable over a long enough time to have produced characteristic soil profiles. The three Great Soil Groups - Gray-Brown Podzolic, Brunizem (prairie), and Humic Gley - as mapped for northeastern Illinois by Wascher et al (1960), show a remarkably high degree of correlation with the presettlement vegetation map presented in this paper. However, no definite correlation was found between Fig. and glacial 'parent materials' as shown by Wascher et al (1960).

Savanna. This vetetation type generally occupied the rolling uplands of the county. These uplands are frequently broken by small wetlands or streams; thus fires would have been less severe in these locations than on the flat prairie lands. In some instances, areas of high topographic relief were correlated with prairie-savanna boundaries, such as the eastern end of "Long Grove" (Fig. 1).

The tree composition of savanna as recorded by the surveyors in nearby Kane County, Illinois (Kilburn 1955, 1959), and Racine County, Wisconsin (Goder 1956) are similar to that recorded for Lake County. In Lake County, bur oak was by far the most common arboreal species, with black and white oak in lesser numbers (Table 4). Curtis (1959) suspected that introgression from bur oaks had conveyed an extra degree of fire resistance to the white oaks, since he observed that some white oaks have bark that appears thicker than normal. One such hybrid (Quercus x bebbiana) was collected in Lake County east of Lake Villa in 1851 (Jones and Fuller 1955). Black oak, pin oak and red root were frequently listed in the understory of savanna. All the species listed in Table 2, except black ash, were recorded by the surveyors in savanna areas.

A peculiar type of savanna existed in the "sand area" (Fig. 1). The surveyors describe it as "Land broken with sand ridges marshy and unfit for cultivation. Timber Black oak, Yellow and White Pine - very scattering." Black oak may still be seen in the sand area today, especially at Illinois Beach State Park, where it forms somewhat dense stands. However, the pines recorded by the surveyors are no longer present within the sand area.

The average corner-to-tree distance recorded by the surveyors in the savanna areas was approximately 30 meters. Eleven per cent of the corners located in savanna had sections where no trees were near enough to blaze, although witness trees may have been recorded in the other sections about that particular point. In some areas there was no definite boundary between savanna and prairie. Reference was frequently made in the field notes to "Scattered" or "Scattering Timber". This and the above generally suggests that savanna trees here in Lake County were separated by large distances.

With the cessation of prairie fires, trees and shrubs likely invaded the savannas. This phenomenon has been studied, using the land survey records, by Cottam (1949) and Ward (1956b). The general outline of these present-day shrubby woodlands can be clearly seen on the 1975 U.S.G.S. topographic maps. A good example of this is the "Long Grove" on the Lake Zurich quadrangle.

Although a savanna community with black oaks is preserved at Illinois Beach State Park, the typical black soil savanna with bur, black and white oaks with a prairie understory is now extinct in the county. A number of large open-grown oaks still exist however, minus the prairie understory, in farmfields, fencerows, pastures and "oak woodlands" throughout the county.

Prairie. Prairie in Lake County was most extensive west of the Des Plaines River, occupying the more level morainic topography. That this prairie was maintained by periodic fires is suggested by the vegetation patterns in Fig. 1. Apparently the fires were swept in an easterly direction by the prevailing westerly winds, restricting the development of forests or groves to the protected eastern sides of lakes and streams. A striking example of this is provided by the Des Plaines River, which probably acted as a firebreak, allowing the development of maple-basswood forest on its east bank. This phenomenon has been similarly noted in other presettlement vegetation studies (Goder 1956, Kilburn 1959, Neuenschwander 1956, Stroessner and Habeck 1966, Tans 1976), and was inves-

Table 3. Witness tree diameter classes as tabulated from original land survey records for Lake County, Illinois.

Species	Diameter class in centimeters																	%
	10	15	20	25	30	35	40	45	50	56	61	66	71	76	81	91	106	Total	Total
Bur oak	9	33	71	139	250	90	47	150	125	9	84	3	1	22	1	7	1	1042	44.4
White oak	-	3	29	59	148	90	40	108	107	18	89	1	2	35	2	12	-	743	31.8
Black oak	-	10	32	37	76	56	13	34	28	-	14	-	-	11	-	2	-	313	13.4
Hickory	-	2	7	18	44	5	1	4	1	-	-	-	-	-	-	-	-	82	3.5
Red oak	-	1	6	2	10	5	2	6	4	-	3	-	-	-	-	-	-	39	1.66
White ash	-	-	1	5	14	1	2	1	-	-	-	-	-	-	-	-	-	24	1.02
Quaking aspen	-	3	-	5	8	3	-	1	-	-	-	-	-	-	-	-	-	20	.85
White pine	-	2	3	2	4	1	-	3	-	-	-	-	-	-	-	-	-	15	.64
Spanish oak	-	2	3	-	1	1	-	1	3	-	4	1	-	-	1	-	-	17	.72
Basswood	-	-	3	2	5	1	-	-	-	-	-	-	-	-	-	-	-	11	.47
Sugar maple	-	-	-	3	3	1	-	2	-	-	-	-	-	-	-	-	-	9	.38
White elm	-	-	-	1	3	2	1	-	-	-	-	-	-	-	-	-	-	7	.29
Ironwood	-	1	2	1	1	-	-	-	-	-	-	-	-	-	-	-	-	5	.21
Black walnut	-	-	-	-	1	-	1	1	1	-	-	-	-	-	-	-	-	4	.17
Birch	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	.08
Cherry	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	.08
Hawthorn	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.04
Cottonwood	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.04
Butternut	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	.04
Jack pine	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.04
Willow	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	.04
																		2340	99.91

tigated and discussed in detail by Gleason (1913).

The traveler Colbee C. Benton traversed the county by horseback in late August of 1883. His records agree with the vegetation patterns shown in Fig. 1. Below is a passage from his diary (Benton 1957) describing the large prairie east of the Des Plaines River in R 12 E, T 43 N. (Fig. 1).

> "Passed across a fine rich prairie covered with a great variety of the most beautiful flowers, some on stalks higher than I could reach from my horse, and those resembled the sun flower in New England, only not quite as large. I have these the name of the "Prairie Sunflower", but I don't know how they will retain that name (Probably referring to Silphium terebinthinaceum, "Prairie Dock".) It was about four miles across this prairie and it was no doubt a continuation of the one I had before seen, as it extended to the south farther than I was able to see. From this prairie it is about two miles through heavy timbered land to the O'Plaine River."

He goes on to mention another extensive prairie west of the Des Plaines River, and gives a description of the scenery and fauna that existed in the northwestern portion of the county (Benton 1957).

Wet Prairie. These areas were distinguished by the surveyor from 'Prairie' on the township plat maps. They are highly correlated with deposits of Grayslake Peat as shown by Willman (1971). It seems quite probable that parts of wet prairies were like fens (Curtis 1959) in composition, due to the high water table in these areas and the calcareous nature (Wascher et al 1960) of the underlying glacial tills.

The distribution of wet prairie between Lake Michigan and the Des Plaines River was largely limited to intermorainal low spots of the Lake Border Morainic System, and to the "swales" between sand ridges in the

Table 4. Importance values of the seven most frequent savanna witness trees.

Species	Corners of occurrence	Rel. Freq. %	Rel. Dens. %	Rel. Dom. %	Imp. Val. (Sum of others)
Bur oak	680	46.5	47.4	46.5	140.4
White oak	433	29.7	32.0	37.6	99.3
Black oak	234	16.0	14.1	11.0	41.1
Hickory	60	4.1	3.4	1.8	9.3
Red oak	18	1.2	.9	1.4	3.5
White pine	9	.6	.7	.3	1.6
Quaking aspen	10	.7	.5	.4	1.6
Spanish oak	11	.8	.5	.9	2.2
Pin oak	5	.4	.2	.08	.7
	1461	100.0	99.7	99.98	299.7

sand area. Fortunately, an undisturbed five acre, wet-mesic prairie dominated by prairie dropseed (Sporobolus heterolepis) still exists on an intermorainal deposit of Grayslake peat near Lake Forest, Illinois. It is probably the last remaining wet-mesic prairie of this type left in the county.

Maple-Basswood Forest. This forest type was restricted by fire to the east side of the Des Plaines River. Why this forest did not extend north on the east side of the Des Plaines River is not known. East of the Des Plaines River the forest is found only upon glacial valley train or alluvial deposits of the Des Plaines River, and does not extend far up onto the moraines which are dominated by oaks. Current work at the Morton Arboretum, Du Page County, Illinois, shows that certain oak forest soils on glacial tills have developed high concentrations of aluminum in the B horizon of the soil. Aluminum in the amounts present is toxic to maples, basswoods and other mesophytic forest species. In such instances, maple and basswood may have a difficult time becoming established in the area, since their roots cannot penetrate the B horizon deep enough to support a mature tree. The perched water table created in the spring by impermeable clay in the morainal tills may also play an important role in preventing the establishment of maple and basswood (Miessenger, pers. comm.).

Maple-basswood forest is also found in the ravines that run eastward into Lake Michigan. Many of the mesic tree species recorded by the surveyors near Lake Michigan were in these ravines and not in the surrounding oak forest on the uplands. Although unrecorded by the surveyors, beech (Fagus grandifolia), occurs in two of the ravines along the Lake Michigan shoreline (Jensen 1929). These ravines were too small to be shown in Fig. 1.

A good example of ravine vegetation has been preserved north of, and adjacent to, the Fort Sheridan Army Base. An excellent example of maple-basswood forest is preserved at the Edward L. Ryerson Conservation Area, near Deerfield, Illinois, a dedicated Illinois Nature Preserve owned and managed by the Lake County Forest Preserve District.

Oak-Hickory Forest. This community was found a short distance east of the Des Plaines River and on the Highland Park Moraine adjacent to the lake (Fig. 1). Many of the original trees of this community can still be seen near Lake Michigan in the residential sectors of the towns of Lake Bluff, Lake Forest, and Highland Park. In adjacent Cook County, the original trees of this same, continuous, community were studied by Waterman (1920). He found the Hill's oak (Quercus ellipsoidalis) to be an important member of this forest.

Swamp and Marsh. The surveyors used the terms swamp and marsh interchangeably. Witness trees were recorded in both areas; no distinct differences in composition could be found. However, treeless section corners were also recorded by the surveyors in both areas. Reference to "Cat Tail Swamp" or, "Swampy Prairie" further add to the confusion of what the surveyors actually saw.

ACKNOWLEDGEMENTS

The author would like to acknowledge the Lake County Forest Preserve District for partial funding of this project, and to Jerrold Soesbe, Director of the Forest Preserve District, and Dan Brouillard, head biologist of the District, for their encouragement on this project. Sincere appreciation is expressed to Dr. Richard D. Newsome, Professor of Biology at Beloit College; Dr. Virginia Kline, plant ecologist, University of Wisconsin, Madison; Charles Bushey, biologist, Lake County Forest Preserve District; and Dr. George Ware, forest ecologist, Morton Arboretum, for their helpful criticisms during the study.

LITERATURE CITED

Anderson, R. C. 1970. Prairies in the prairie state. Trans. Ill. State Acad. Sci. 63:214-22.

Barnes, W. J. 1974. A history of the vegetation of Eau Claire County, Wsiconsin. Trans. Wisc. Acad. Sci. Arts Lett. 62:357-375.

Benton, C. C. 1957. A visitor to Chicago in Indian days. The Caxton Club, Chicago, Ill. 121 p.

Bourdo, E. A. 1956. A review of the General Land Office survey and its use in quantitative studies of former forest. Ecology 37:754-768.

Cottam, G. 1949. The phytosociology of an oak woods in southwestern Wisconsin. Ecology 30:271-287.

Crankshaw, W. B., S. A. Quadir, and A. A. Lindsey. 1965. Edaphic controls of tree species in presettlement Indiana. Ecology 46:688-698.

Curtis, J. T. 1959. The vegetation of Wisconsin. Univ. Wisc. Press, Madison. 657 p.

Ellarson, R. S. 1949. The vegetation of Dane County, Wisconsin in 1835. Trans. Wisc. Acad. Sci. Arts Lett. 39:21-45.

Fernald, M. L. 1950. Gray's Manual of Botany. 8th Ed. American Book Co., N.Y. 1632 p.

Gleason, H. A. 1913. The relation of forest distribution and prairie fires in the middle west. Torreya 13:173-181.

______. 1923. The vegetational history of the middle west. Ann. Assoc. Amer. Geog. 12:39-85.

Goder, H. A. 1956. Presettlement vegetation of Racine County. Trans. Wisc. Acad. Sci. Arts Lett. 45:169-176.

Halsey, J. J. 1912. History of Lake County, Illinois. Harmegnies and Howel, Chicago. 879 p.

Jensen, J. 1928. The native beeches of the Chicago region. Trans. Ill. State Acad. Sci. 21:69-71.

Jones, G. N., and G. D. Fuller. 1955. Vascular plants of Illinois. Univ. Ill. Press, Urbana. 593 p.

Kenoyer, L. A. 1930. Ecological notes on Kalamazoo County, Michigan, based on the original land survey. Mich. Acad. Sci. Arts Lett. 11:211-217.

______. 1933. Forest distribution in southwestern Michigan as interpreted from the original land survey 1826 - 1832. Mich. Acad. Sci. Arts Lett. 19:107-111.

Kilburn, P. D. 1955. The original vegetation of Kane County, Illinois. M.S. Thesis. Univ. Mich., Ann Arbor. 34 p.

______. 1959. The prairie-forest ecotone in northeastern Illinois. Amer. Mid. Nat. 62:206-217.

Lutz, H. J. 1930. Original forest composition in northwestern Pennsylvania as indicated by early land survey notes. J. For. 28:1098-1103.

Musselman, L. J., T. S. Cochrane, W. E. Rice, and M. M. Rice. 1971. The flora of Rock County, Wisconsin. Mich. Bot. 10:147-193.

Neuenschwander, H. E. 1956. The vegetation of Dodge County, Wisconsin, 1833-1837. Trans. Wisc. Acad. Sci. Arts Lett. 46:233-254.

Potzger, J. E., and M. Potzger. 1950. Composition of the forest primeval from Hendricks County southward to Lawrence County, Indiana. Proc. Ind. Acad. Sci. 60:109-113.

Shimek, B. 1915. The plant geography of Lake Okoboji region. Lab. Nat. Hist. State Univ. Iowa 7(2):3-69.

Stroesener, W. J., and J. R. Habeck. 1966. The presettlement vegetation of Iowa County. Trans. Wisc. Acad. Sci. Arts Lett. 36:141-161.

Tans, W. 1976. The presettlement vegetation of Columbia County, Wisconsin in the 1830's. Dept. Nat. Resources Tech. Bull. No. 90. 19 p.

Vestal, A. G. 1931. A preliminary vegetation map of Illinois. Trans. Ill. State Acad. Sci. 23:204-217.

Ward, R. T. 1956a. The beech forests of Wisconsin - changes in forest composition and the nature of the beech border. Ecology 37:408-418.

______. 1956b. Vegetational changes in a southern Wisconsin township. Proc. Iowa Acad. Sci. 63:321-326.

Wascher, H. T., J. D. Alexander, B. W. Ray, A. H. Beavers, and R. T. Odell. 1960. Characteristics of soils associated with glacial tills in northeastern Illinois. Univ. Ill. Ag. Exp. Sta. Bull. No. 665. 155 p.

Waterman, W. A. 1920. Distribution of oaks on the Lake Chicago bars in Evanston and New Trier townships. Trans. Ill. State Acad. Sci. 13:239-242.

Willman, H. B. 1971. Summary of the geology of the Chicago Area. Ill. Geol Surv. Circ. 460. 77 p.

Wuenscher, J. E., and A. G. Valiunas. 1967. Presettlement forest composition of the River Hills region of Missouri. Am. Mid. Nat. 78:487-495.

MAPPING THE PRE-SETTLEMENT PRAIRIES OF MISSOURI

Walter A. Schroeder

Department of Geography
University of Missouri
Columbia, Missouri 65201

ABSTRACT

This is a status report of the success and problems of a multiyear project of mapping the pre-settlement prairies of Missouri. About one third of the state has been completed; another one third is nearing completion. Methodology includes preliminary use of historic atlases, basic dependency on the U.S. Land Office surveys, and interpolation from soils and topographic maps. While certain regions had sharp boundaries between prairie and timber, much of Missouri exhibited varying mixtures of grasses, bushes, vines, and trees. Statistics of the geographical extent of former prairie area are being kept by congressional township and county, and a gazetteer of historic and contemporary prairie place names is being compiled.

INTRODUCTION

The purpose of this paper is to report on the status of a multiyear project to map the pre-settlement prairies of Missouri. An understanding of the problems encountered in the project and how they were resolved is necessary if the map is to be useful and properly interpreted.

PROBLEMS

The foremost problem is the vegetative or botanical definition of prairie. Where the grassland-timber boundary was abrupt, there is no question of definition, but in many landscapes of Missouri there were no such boundaries. Grasses, trees, brush and vines all intermingled, and the change from timber to grassland was marked by transitional zones. For example, this verbal description of a part of the Ozarks by Schoolcraft (1819) may or may not be that of a prairie: "The hills also yield sassafras, and the slopes which are richer soil, afford buckeye, black walnut, papaw, and percimmon... and the whole is covered in summer by a luxuriant growth of grass..." As another example, it is not clear whether the land described in the following terse expressions from the field notes of the U. S. Land Office survey from widespread sections of Missouri should be mapped as prairie: "brushy barrens," "undergrowth," "hazel brush," "prairie with scattering scrubby trees," "brush thick as hair on a dog's neck," "timber with grass," "vines."

The term "glade" is particularly troublesome for mapping. The Missouri Prairie Foundation and others (Bourne 1820) tend to refer to certain glades as prairies, with good reason. However, after reading historic descriptions elsewhere (Sauer 1920, Marbut 1911), I am convinced that before 1850 or so the term "prairie" was not used for glades, and glades were not so regarded by their inhabitants.

Historically, the term prairie has meant different things to different people. The French who settled along the Mississippi River is Missouri and traveled along almost all the rivers in the state north of the Ozarks, applied their native French term "prairie" liberally to grassy wet bottom-lands, thin-soil karst uplands, and to the "true" tall-grass prairie (Alderson 1849-1850, Harrison 1943, Hamlett 1938, Peterson 1949; Perrin du Lac map of 1802). But the Ozarks were settled by folk migrating from the middle Appalachians, through Kentucky and Tennessee, and to whom "prairie" was literally a foreign term. Their vocabulary did include such terms as "glades," "barrens," "balds," "grassy" as an adjective in "grassy knob," or "shut-in plains" (Clendenen 1973). Therefore, the same visual landscape that may have been labelled a prairie in parts of Missouri may not have been in other parts. Furthermore, settlers coming from forested country east of the Mississippi may have overemphasized the openness of the Ozarks woods and the barrens because these landscapes were so unusual to their experiences (Steyermark 1959). In short, there is no standard usage of "prairie" in historical documents on Missouri. Therefore, for this mapping project a definition of prairie as an open and complete grassland without trees has been adopted. There must be no indication of extensive brush, vines, or trees. Barrens and glades are excluded.

A second problem concerns time. If settlement means white American settlement, how much "pre" is permitted in the term "pre-settlement"? The journals of Lewis and Clark and others refer to named prairie tracts, along the Missouri River in Missouri, to which the names had already been given by French fur traders apparently in the late eighteenth century. However, these same prairies cannot be identified in the field notes of the U. S. Land Office survey only twenty-five years later (Coues 1893). For this mapping project only those prairies identifiable at the time of the Land Office survey are being mapped.

It is important to note that all the time discrepancies in the pre-settlement prairies the author has encountered are of one nature: land that was earlier prairie was later described as timber and never vice versa, from earlier timber to later prairie. This is an important piece of evidence for believing that forests were expanding at the expense of prairies in the early nineteenth century in Missouri (Sauer 1920).

Figures 1 and 2 show the results of mapping prairies from different sources. Figure 1 is taken from a map in the Missouri State Plan of 1938. The unshaded areas presumably are "original prairie." According to its caption, it is based on soil maps; soils whose development has been associated with grasses supposedly would indicate former prairies. There are some difficulties with this. Particularly bothersome is the rapid intrusion of timber onto former prairie land in some areas just before white settlement, as mentioned above. Because the characteristics of soils change more slowly than the vegetation growing on them, regions of recent forest intrusion would show up on Figure 1 as prairie, but on a map based on U. S. Land Office field notes, the same region would be described as timber. Conversely, this map curiously omits some well-known pre-settlement prairies, such as the Kickapoo Prairie at Springfield and the prairies of the Missouri Bootheel.

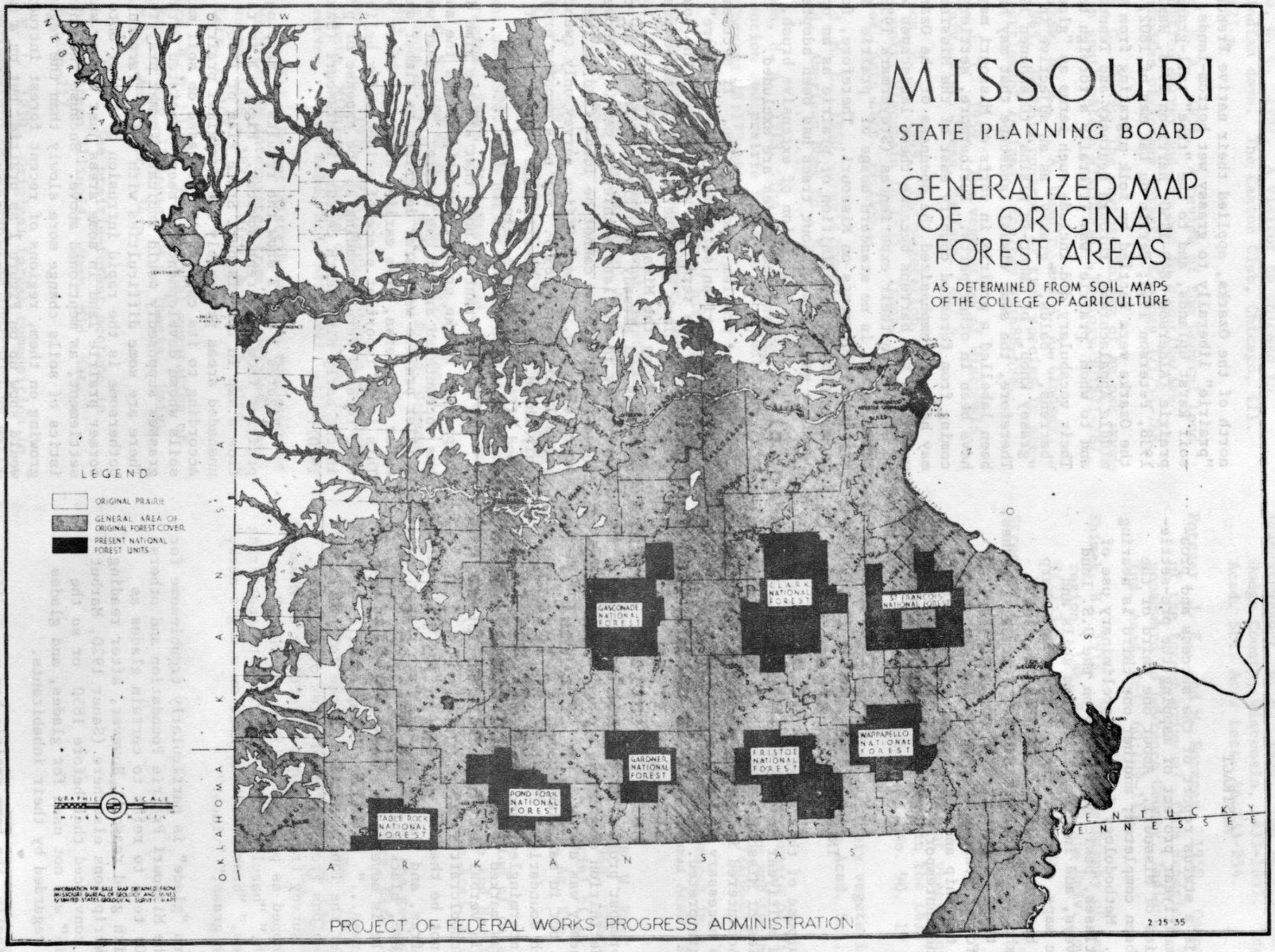


Fig. 1. Original prairie areas of Missouri according to the Missouri State Plan of 1938. White areas indicate "original prairies" as determined from soil maps.

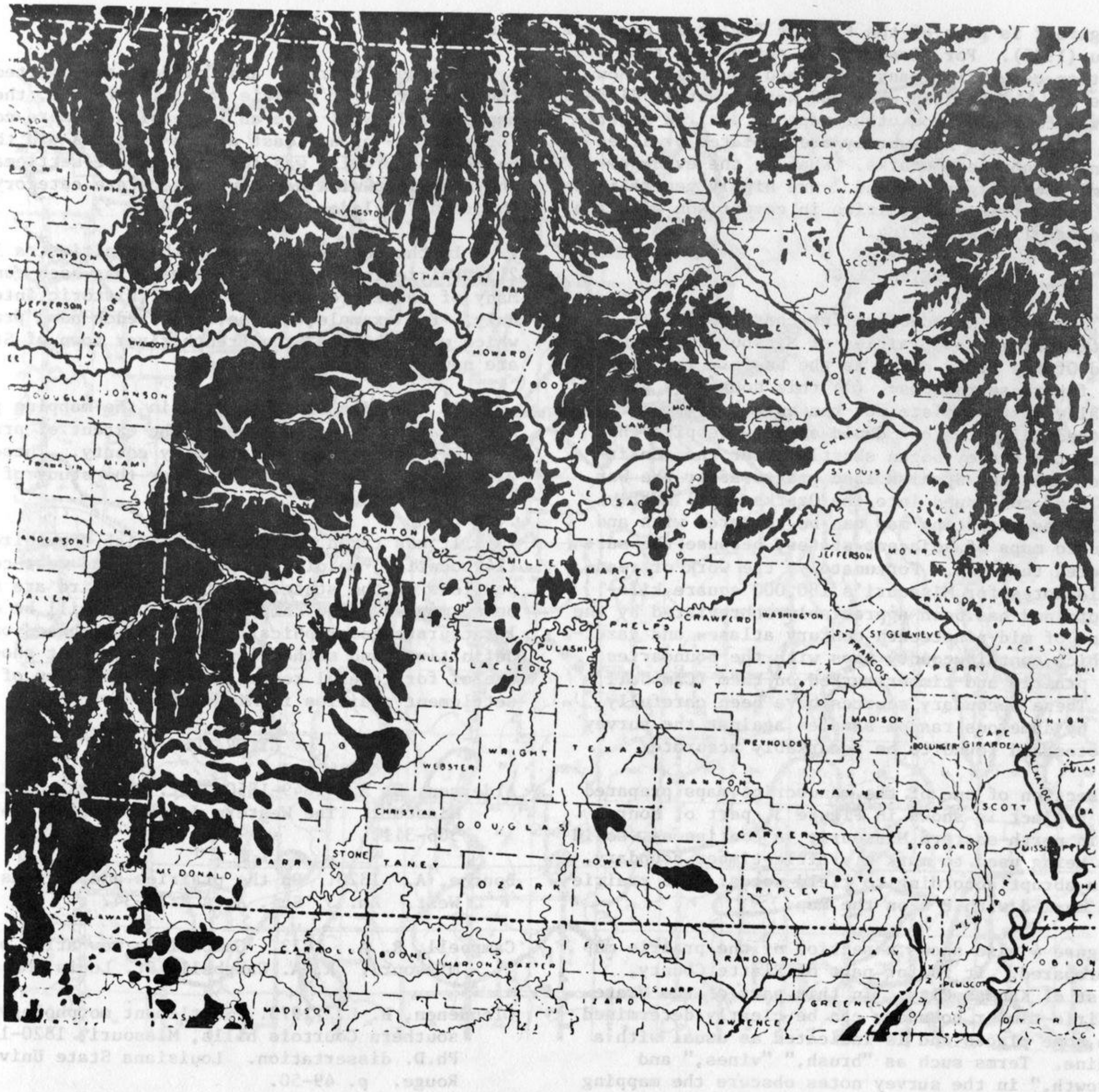


Fig. 2. Prairies of Missouri from Transeau (1935). Shaded areas indicate prairies. Basis of prairie identification is not known.

Figure 2 is part of the Prairie Peninsula map from Transeau (1935). For Missouri, he noted only that his information came "from many published sources." How can this map be verified when one notes that it differs in several counties from other maps of prairie distribution? Especially noteworthy are isolated prairies shown in the northern Ozarks. What is the evidence for them? Both Figures 1 and 2 are highly generalized maps of pre-settlement prairies in comparison with the detailed map I am producing.

METHODOLOGY

My choice of methodology for construction of a pre-settlement map of prairies of Missouri is to use the Land Office field notes as the basis. The choice is made for these reasons: (1) this source is geographically most complete for the entire state; (2) it is as standardized as one could expect, despite the fact that the survey began shortly after the confirmation of existing Spanish land grants after the War of 1812, and continued into the Ozarks until nearly 1850; (3) the resulting map can be compared with and added on to maps of adjacent states, because the survey covered them too. Fortunately, the work of reading field notes for Missouri's 180,000 square kilometers of land has been appreciably abbreviated by the existence of mid-nineteenth century atlases and gazetteers which contain county maps with the boundaries between prairie and timber marked on them (Campbell 1873). These secondary sources have been carefully checked by numerous random samples against the survey field notes and found to be remarkably accurate.

A section of one of the manuscript maps prepared in this project is shown in Figure 3, part of Monroe County in north-eastern Missouri. A continuous, solid line is being used to mark a prairie-timber boundary, which is abrupt according to field notes. The prairie area is marked with P's on the map.

Figure 4 also shows a section of the prairie map being prepared. It is for part of Platte County, northwest of Kansas City. In this part of the state the prairie-timber boundary can be clearly determined only in some places and is indicated as usual with a solid line. Terms such as "brush," "vines," and "overgrowth," in the survey notes obscure the mapping of the prairie-timber line elsewhere. In these cases, a determination of the limits of prairie has been made from topographical evidence, by drawing a line to correspond with the same topographic break that characterizes other places where the prairie limit is clear. To keep this extrapolated line distinct from the line drawn directly from vegetative terms in survey notes, a dotted line is used. As a last step, where no obvious relationship with topography exists, a straight line is drawn connecting the known ends of the line. This is shown on the manuscript maps with a dashed line. The use of three different lines on the maps informs the user precisely on what kind of information the line was based.

Information from soils is not being used at all for this mapping project. In those counties where it was experimented with, it was found almost useless. For example, prairies inferred from prairie soils mapped in the Howard County, Missouri, soil survey do not agree at all with the prairies described and mapped in the field notes of the Land Office survey (Schroeder 1968). The former were fifty times more extensive than the latter. Also, accurate and modern soils surveys do not exist for many counties of Missouri.

Because "barrens" and "glades" are omitted from the definition of prairie for this project, the final map probably will give an impression of more complete forestation--or at least a lack of grass--in the Ozarks than really was the case in pre-settlement days. The final map will not have a separate category for "barrens," "glades," or "savanna."

In the course of mapping the prairies, a list of 215 prairie toponyms (place names) has been compiled. Many of these are obsolete and of historic interest only. For example, the several French-name prairies which were "behind" the French river town of St. Louis are now thoroughly urbanized.

As counties are completed in the mapping project, a tabulation is being made of the extent of prairie by congressional township and by county. These data will serve as a historic base for the study of changing land use.

It has taken ten years to finish one third of the 114 counties, mainly in the central and west-central portions of the state. Another one third are now being mapped. The complete state map will be extremely accurate geographically and will be based on stated definitions and methodology. Therefore it should be useful for careful research on the location of pre-settlement prairies in Missouri.

LITERATURE CITED

Alderson, B. A. 1849-1850. St. Charles county, Missouri. The Western J. (St. Louis) 3:46-48, 306-311.

Bourne, A. 1820. On the prairies and barrens of the West. Am. J. Sci. Arts 2:30-34.

Campbell, R. A. 1873. Campbell's new atlas of Missouri. R. A. Campbell, St. Louis, Mo.

Clendenen, H. L. 1973. Settlement morphology of the southern Courtois hills, Missouri, 1820-1860. Ph.D. dissertation. Louisiana State Univ, Baton Rouge. p. 49-50.

Coues, E. 1893. History of the expedition under the command of Lewis and Clark. Francis P. Harper, New York. 1:39-40.

Hamlett, M. L. 1938. Place-names of six southeast counties of Missouri. M.S. thesis. Univ. Missouri, Columbia. p. 118.

Harrison, E. L. 1943. The place names of four river counties in eastern Missouri. M.S. thesis. Univ. Missouri, Columiba. p. 97, 103, 276.

Marbut, C. F. 1911. Soil reconnaissance of the Ozark region of Missouri and Arkansas. U. S. Dept. Agr. Bur. Soils. p. 1727-1872.

Peterson, C. E. 1949. Colonial St. Louis: Building a Creole capital. Missouri Historical Society, St. Louis. p. 14-18.

Sauer, C. O. 1920. The geography of the Ozark highland of Missouri. Geog. Soc. Chicago Bull. 7:53-54, 56.

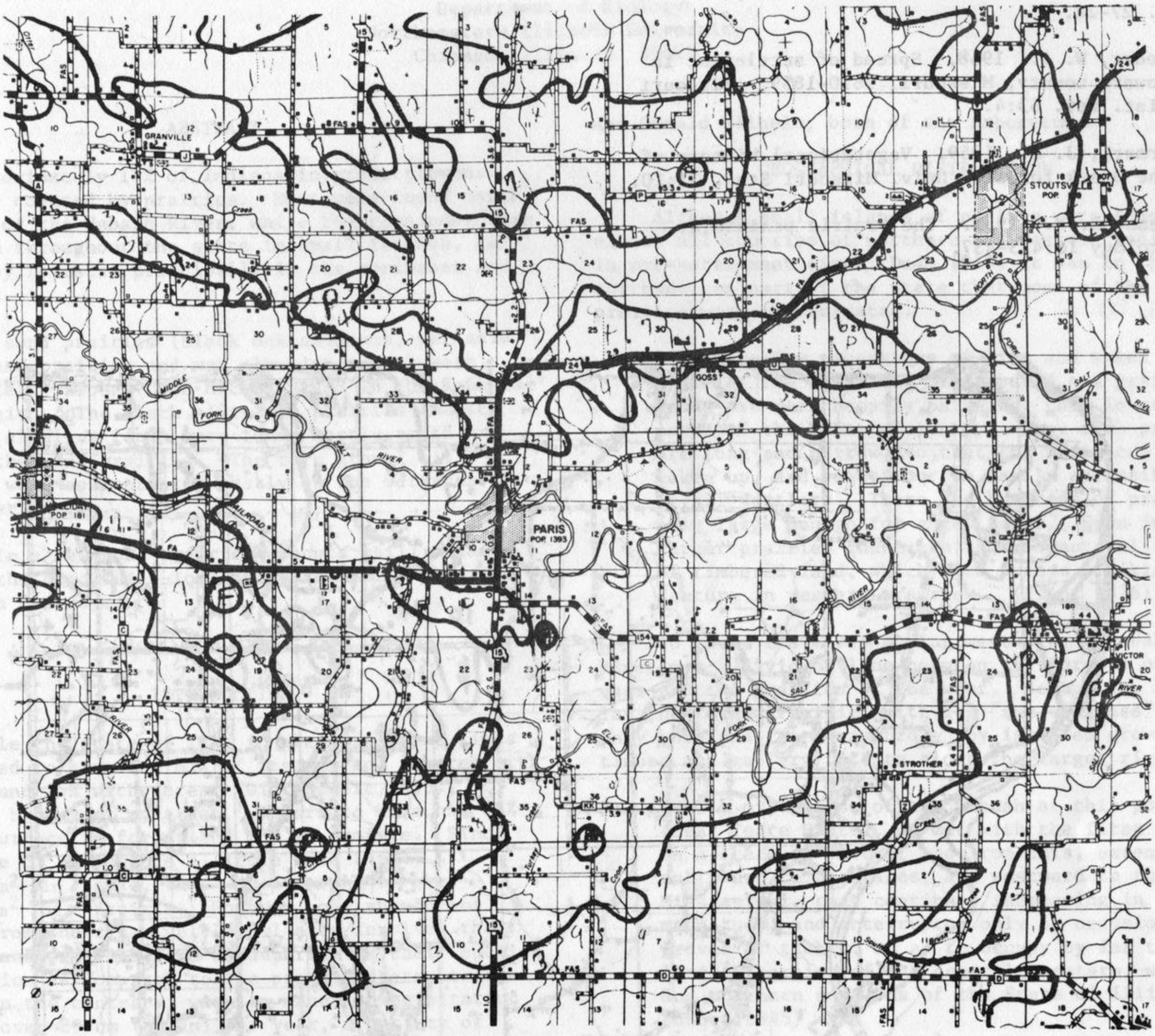


Fig. 3. Manuscript map of part of Monroe County, Missouri. The solid line marks the boundary between prairie and timber, according to U. S. Land Office field notes. Shaded areas are prairie.

Schoolcraft, H. R. 1819. A view of the lead mines of Missouri. Charles Wiley & Company, New York. p. 27-28.

Schroeder, W. A. 1968. Spread of settlement in Howard county, Missouri, 1810-1859. Missouri Hist. Rev. 63:4.

Steyermark, J. A. 1959. Vegetational history of the Ozark forest. Univ. Missouri Stud. 31:10.

Transeau, E. N. 1935. The prairie peninsula. Ecology 16:423-437.

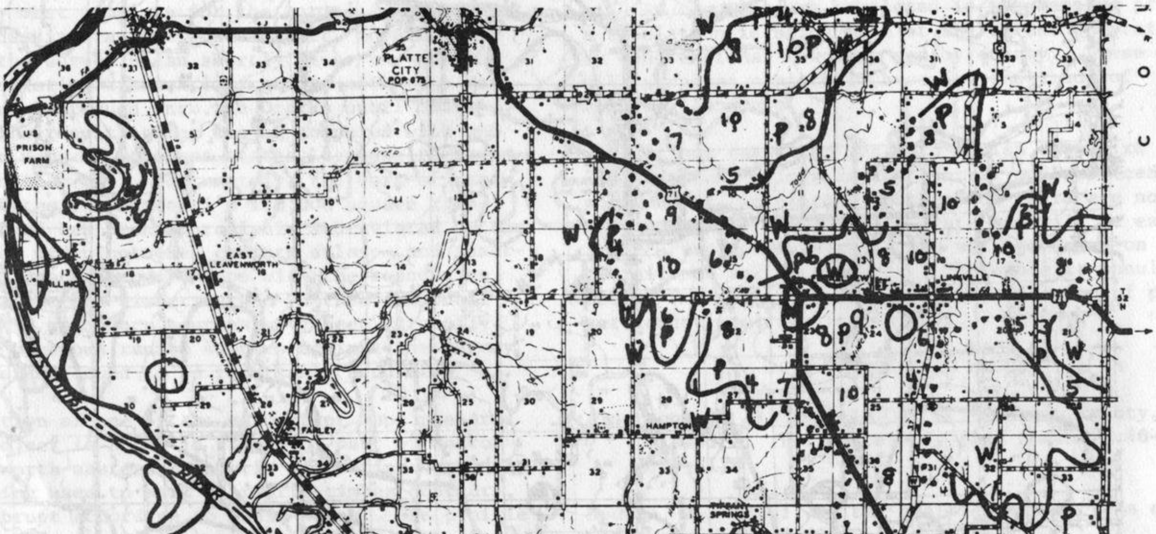


Fig. 4. Manuscript map of part of Platte County, Missouri. The solid line marks the known boundary between prairie and timber, as identified in the U. S. Land Office field notes. The dotted line marks the boundary inferred from topographical relations. Shaded areas are prairie.

THE PRAIRIES OF INDIANA

Robert F. Betz

Department of Biology
Northeastern Illinois University
Chicago, Illinois 60625

ABSTRACT

Approximately 15% of Indiana in presettlement times was covered by prairies. Most were found north and west of the Wabash River, while the remainder were scattered throughout the state in small islands, surrounded by forests, principally in the northeast and southwest.

The sand prairies (black oak savannas, wet acid sands, sand prairies and wet alkaline sands) were found chiefly around Lake Michigan and in the Kankakee River region. The black silt-loam prairies (mesic, wet, and alkaline fens) were found mostly south and east of the sand prairies. The rare gravel hill prairies were concentrated mostly on the terraces of the larger rivers.

While a few sand prairie remnants still exist, most of the black silt-loam and gravel hill prairies have been destroyed.

INTRODUCTION

While the state of Iowa in pre-settlement times is reputed to have had 85% of its surface covered with prairie and 15% with forest (Dick-Peddie 1955), Indiana, by way of contrast, appears to have had 85% of its surface in forest and 15% in prairie. Since the state of Indiana is a little more than 93,240 km^2 in size, this would amount to over 12,950 km^2 of prairie. However, one should not assume from the relatively small area involved that the Indiana prairies were depauperate in their species composition as compared to the prairie states to the west. On the contrary, with an annual precipitation of well over 89 cm (35 in) per year, a variety of soils, and a variety of plant species drawn from all parts of North America, such as lead plant (Amorpha canescens) and prairie parsley (Polytaenia nuttallii) from the southwestern prairies, and rockroses (Helianthemum sp.) and pin weeds (Lechea sp.) from the Atlantic coastal plain (Peattie 1922), all made the Indiana prairies extremely rich in species. The dune area at the south end of Lake Michigan, with its mosaic of forest, prairie, marsh and bog, is probably one of the richest botanical areas in the entire Middle West.

Unfortunately, very little is known about these prairies. Articles on Indiana prairies are few and usually of a general or theoretical nature (Benninghoff 1963, Finley and Potzger 1951, Rohr and Potzger 1951, Welch 1929). However, a small number of papers are devoted to their species composition and ecology (Bliss and Cox 1964, Friesner and Potzger 1946, Starc 1961). Some ecological information can be found in Peattie's Flora of the Indiana Dunes (1930), Deam's Flora of Indiana (1940) and Swink's Plants of the Chicago Region (1974). Another valuable source of information on these prairies has come from the detailed ecological labels on specimens in the herbarium of the Morton Arboretum, Lisle, Illinois, collected during the past decade by Ray Schulenberg and Gerald Wilhelm, both of the Arboretum.

GEOGRAPHICAL DISTRIBUTION

Although small islands of prairie were found in almost all counties of northern and western Indiana in pre-settlement times (Deam 1940) it was in the northwestern part of the state that most of the prairies were concentrated:

> With some few exceptions of wide and naked prairie, the divisions of timbered and prairie lands are more happily balanced, than in other parts of the western country. Many rich prairies are long and narrow, so that the whole can be taken up, and yet timber be easily accessible by all settlers. There are hundreds of prairies only large enough for a few farms. Even in the larger prairies there are those beautiful islands of timbered land, which form such a striking feature in western prairies. (Flint 1826).

To early travelers moving westward, the Wabash River was a dividing line between the forests of the east and the prairies of the west. Beyond the river lay the "Grand Prairie" with its "sea of grass", which only here and there was broken by isolated groves of timber and gallery forests along the larger rivers:

> Twenty miles west of the Wabash at this point (near Terre Haute), we met with the first prairie in a state of nature; and from this, extending northward to the Lakes, and westward to the Mississippi, they continue, increasing in magnitude, and interrupted only by occasional groves of timber, so as to occupy by far the largest portion of the central, eastern, western, and northern portions of the State of Illinois (Short 1845).

A study of Transeau's (1935) map (Fig. 1) drawn from data obtained from the distribution of soil types and the field notes of the early surveyors, clearly shows the preponderance of prairie and prairie marsh vegetation in northwestern Indiana. Extending northeastward and eastward in long finger-like projections, the prairie penetrated deep into the forested regions of Indiana. Further eastward this grassy sward, with its groves and savannas, faded into an unbroken forest with isolated patches of prairie all the way to the eastern-most counties of Indiana and beyond into Ohio.

Because of differences in soil type, these Indiana prairies were not all alike. While many similarities existed among them, the sand prairies of Stark and Pulaski counties in the north differed considerably from the black silt-loam prairies of Benton and Warren counties to the south. The pre-settlement prairies in Indiana can be divided into three major types: (1) sand prairies and black oak savannas, (2) black silt-loam prairies, and (3) dry gravel hill prairies.

A study of the physiographic units of Indiana (Fig. 2) clearly shows the peculiar distribution of

Fig. 1. Map of Indiana showing the distribution of major types of prairies and savannas in presettlement times. Modified from E.N. Transeau (1935), Ecology 16: 423-457.

sand and glacial till which gave rise to the sand and silt-loam areas on which the prairies developed. The sand region of northwest Indiana is divided into two unequal parts by the 24-32 km (15-20 mile) wide Valparaiso Moraine, viz., the relatively small Calumet Lacustrine Plain (Lake Chicago Plain) in the northern parts of Lake, Porter and LaPorte counties, and the much larger Kankakee Outwash Plain in the southern parts of Lake and Porter counties, major portions of Newton, Jasper, Stark, St. Joseph, and parts of Marshall, Fulton, Cass and White counties. To the south of the sand area is a region of glacial till (Tipton Till Plain). Superimposing Transeau's Map (Fig. 1) on that of the physiographic units (Fig. 2), reveals the banded arrangement of the Indiana prairies. Beginning at the head of Lake Michigan and moving southward, the presettlement Indiana prairies are arranged in the following way: a northern belt of sand prairies and savannas of the Calumet Lacustrine Plain, followed by black silt-loam prairies of the Valparaiso Moraine, another belt of sand prairies and savannas of the Kankakee Outwash Plain, and finally a belt of black silt-loam prairies of the Tipton Till Plain. This rather simplified arrangement is complicated by the presence of groves, marshes and brush scattered along the prairie communities.

The prairies outliers in the Morainal Lake Area of northeastern Indiana, such as Jackson Prairie in Steuben county, Turkey Prairie in Kosciusko and English Prairie in northern LaGrange counties, are built on sandy loams or loamy sands and have characteristics of both the sand and black soil prairies. The prairie outliers in the eastern parts of the Tipton Till Plain, such as the Cabin Creek Raised Bog (fen) in Randolph county, are black silt-loam prairies.

The third major type, the dry gravel hill prairie, was limited to the gravel terraces (or breaks) along the larger rivers, such as the Wabash and White.

FLORAL COMPOSITION

The Indiana prairies usually contain varying numbers and mixtures of grass species which are usually considered as dominants in the tall grass prairies. Depending on the type of soil, height of the water table, geographical area and the amount of disturbance, one or more species are likely to be present in greater amounts than the others. In general, little blue stem (Andropogon scoparius) and porcupine grass (Stipa spartea) are major components in dry sand prairies and black oak savannas, bluejoint grass (Calamagrostis canadensis) and prairie cord grass (Spartina pectinata) in wet prairies, and side-oats grama grass (Bouteloua curtipendula) a major dominant in calcareous dry prairies. Big bluestem grass (Andropogon gerardii) and Indian grass (Sorghastrum nutans) play a domiannt role in the mesic black silt-loam prairies, but are common in almost all types of prairie. Switch grass (Panicum virgatum) tends to form rather heavy stands in lightly disturbed, periodically wet prairies, while prairie dropseed (Sporobolus heterolepis) tends to become a dominant in virgin mesic prairies with a long history of freedom from disturbance.

While the dominant prairie grasses, with their rather wide ecological amplitudes, provide the background to the various kinds of prairies, it is the presence (or absence) of certain species of prairie forbs that helps in separating the different kinds of Indiana prairies. Using these forbs as indicators, together with the dominant grasses, one can distinguish three different types of Indiana sand prairies, three types of black silt-loam prairies and one type of dry gravel hill prairie.

THE SAND PRAIRIES

Approximately half of the pre-settlement prairies in Indiana were sand prairies and black oak savannas. While the two sand prairie regions of Indiana held many species in common, there were differences in the numbers and kinds of prairie forbs. In general, the prairies in the Calumet region were richer than those in the Kankakee region. There appear to be three different types of Indiana sand prairies: (1) dry sand prairies and black oak savannas; (2) wet, acid sand prairies and (3) wet, alkaline sand prairies.

Dry Sand Prairies and Black Oak Savannas. These prairies are found throughout the sand regions of Indiana on sand ridges and dunes. The dominant grass is little bluestem which occurs usually in compact clumps.

It would appear that in pre-settlement times this plant community was primarily dry sand prairie with a light scattering of black oak (Quercus velutina), which was maintained by the recurring prairie fires that swept through the region. With the cessation of these fires at the time of settlement, the black oaks increased at the expense of the prairie vegetation, resulting in a even age stand of black oak woodland with a depauperate ground cover of small shrubs, such as blueberry (Vaccinium sp.) and huckleberry (Gaylussacia baccata), woodland plants, such as wild sarsaparilla (Aralia nudicaulis) and Solomon's seal (Polygonatum canaliculatum), and a few species of remnant sand prairie palnts. Although never plowed, many of these present-day black oak woodlands are almost beyond recovery as prairie without some cutting of the timber, coupled with annual fires and good prairie management. Some characteristic species of this community are:

Amorpha canescens (lead plant)
Asclepias tuberosa (butterfly weed)
Aster linariifolius (flax-leaved aster)
Baptisia leucantha (white wild indigo)
Coreopsis lanceolata (sand coreopsis)
Helianthemum sp. (frost weeds)
Helianthus occidentalis (Western sunflower)
Lechea sp. (pinweeds)
Lespedeza capitata (round-headed bush clover)
Liatris aspera (rough blazing star)
Lithospermum croceum (hairy puccoon)
Lupinus perennis occidentalis (wild lupine)
Opuntia humifusa (prickly pear)
Phlox bifida (sand phlox)
Quercus velutina (black oak)
Tephrosia virginiana (hoary pea)

Wet Acid Sand Prairies (Wet Sand Prairies). These prairies are found in the swales and other low places in the sand regions of Indiana. Before the digging of drainage ditches in the Kankakee Outwash Plain, they were much more extensive than at present:

> It (the Kankakee River) being very crooked and the land on either side being low and marshy, the water moves off very slowly, and these low lands, forming what is familiarly known as the KANKAKEE MARSH, are for quite a period of time each year covered with from one to three feet of water.

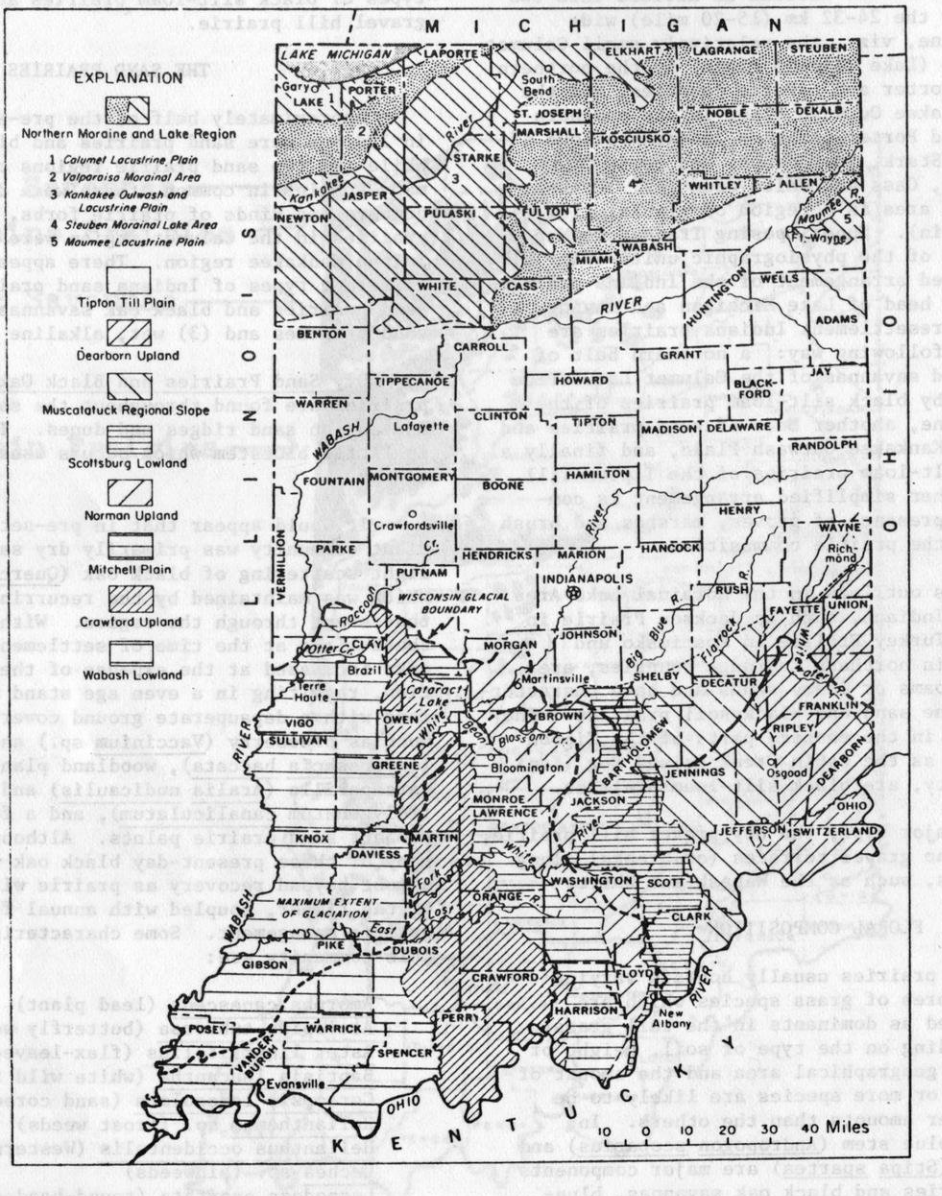


Fig. 2. Map of Indiana showing physiographic units and glacial boundaries. Modified from Indiana Geol. Survey Rept. Prog. 7., fig. 1.

> About six sections of this marsh land in the southeast corner of our county (Lake) are covered with timber, composed....... The balance of these wet lands, running west to the State line, is open marsh, covered with a luxuriant growth of wild grasses, wild rice and flags.....The number of acres of this wet land in the Kankakee valley in Lake county is about sixty thousand, and in the seven counties through which the Kankakee river flows in this State is about six hundred thousand. (Brown 1884).

Blue-joint grass and prairie cord grass are the dominant grasses. Some characteristic species of this community are:

Aletris farinosa (colic root)
Asclepias hirtella (green milkweed)
Calopogon pulchellus (grass pink orchid)
Gentiana saponaria (soapwort gentian)
Gerardia purpurea (purple false foxglove)
Habenaria lacera (ragged fringed orchid)
Houstonia caerulea (bluets)
Osmunda cinnamomea (cinnamon fern)
Osmunda regalis spectabilis (royal fern)
Polygala cruciata (cross milkwort)
Viola lanceolata (lance-leaved violet)

Wet Alkaline Sand Prairies. These prairies are confined to the low swales in the dune region within two km or so of Lake Michigan. The calcareous waters of the lake moving up through the sand produces an alkaline condition which enables a community of calciphiles (together with other prairie species) to thrive. The dominant grasses are similar to those of the wet acid sand prairies. Some characteristic species are:

Aster ptarmicoides (stiff aster)
Buchnera americana (blue hearts)
Cypripedium reginae (showy lady's slipper)
Gentiana crinita (fringed gentian)
Hypericum kalmianum (Kalm's St. John's wort)
Liatris cylindracea (cylindrical blazing star)
Liparis loeselii (green twayblade)
Potentilla fruticosa (shrubby cinquefoil)
Sabbatia angularis (rose gentian)
Tofieldia glutinosa (false asphodel)

BLACK SILT-LOAM PRAIRIES

Disregarding some geographical differences, these silt-loam prairies are similar to those found in Illinois and Iowa. There appear to be three different types: (1) mesic (or upland), (2) wet (or lowland), and (3) alkaline fens.

Mesic Prairies. These prairies are found on the better drained parts of the moraines and till plains. Because of their high agricultural value, they were destroyed early in the settlement period, and for that reason very few remnants exist today in Indiana. The dominant grasses are prairie dropseed, big bluestem, and Indian grass. Some characteristic species are:

Amorpha canescens (lead plant)
Anemone cylindrica (thimbleweed)
Asclepias viridiflora (green milkweed)
Aster laevis (smooth blue aster)
Baptisia leucophaea (cream wild indigo)
Ceanothus americanus (New Jersey tea)
Coreopsis palmata (prairie coreopsis)
Eryngium yuccifolium (rattlesnake master)
Gentiana puberula (prairie gentian)
Liatris pycnostachya (prairie blazing star)
Lilium philadelphicum andinum (prairie lily)
Oxalis violacea (purple sorrel)
Panicum leibergii (Leiberg's panic grass)
Petalostemum candidum (white prairie clover)
Petalostemum purpureum (purple prairie clover)
Phlox pilosa (prairie phlox)
Prenanthes aspera (rough white lettuce)
Ratibida pinnata (yellow cone flower)
Silphium laciniatum (prairie compass plant)
Silphium terebinthinaceum (prairie dock)
Solidago rigida (prairie goldenrod)
Viola pedatifida (prairie violet)

Wet Prairies. These prairies are found on the lower poorly drained portions of moraines and till plains. Like the mesic prairies they were destroyed because of their high agricultural value. With the advent of tile drainage in the latter part of the nineteenth century their fate was sealed; remnants are not common in Indiana today. The dominant grasses are prairie cord grass and blue-joint grass. Some characteristic species are:

Asclepias sullivantii (prairie milkweed)
Cacalia tuberosa (Indian plantain)
Galium obtusum (wild madder)
Gentiana andrewsii (bottle gentian)
Habenaria leucophaea (white fringed orchid)
Lilium michiganense (Turk's cap lily)
Lysimachia quadriflora (narrow-leaved loosestrife)
Oxypolis rigidior (cowbane)
Phlox glaberrima interior (marsh phlox)
Prenanthes racemosa (glaucous white lettuce)
Thalictrum dasycarpum (purple meadow rue)
Zizia aurea (golden Alexanders)

Alkaline Fens. These prairies are found on the low, springy, calcareous parts of moraine and till plains. They are more common in the eastern prairies of Indiana and Ohio, than on the prairies to the west. The dominant grasses are prairie cord grass and blue-joint grass. Some characteristic claciphilic species found in this community are:

Angelica atropurpurea (great angelica)
Cirsium muticum (swamp thistle)
Chelone glabra (turtlehead)
Cypripedium candidum (white lady's slipper)
Filipendula rubra (queen-of-the-prairie)
Lobelia kalmii (Kalm's lobelia)
Parnassia glauca (grass-of-Parnassus)
Pedicularis lanceolata (marsh betony)
Solidago ohiensis (Ohio goldenrod)

DRY GRAVEL HILL PRAIRIES

In pre-settlement times these prairies were probably uncommon in Indiana and confined for the most part to the gravel terraces (or breaks) of the Wabash and White River valleys. The dominant grasses are side-oats grama grass, little bluestem, and porcupine grass. Some characteristic species are:

Allium cernuum (nodding wild onion)
Amorpha canescens (lead plant)
Arenaria patula (slender sandwort)
Aster oblongifolius (aromatic aster)
Astragalus tennesseensis (Tennessee milk vetch)
Kuhnia eupatorioides corymbulosa (false boneset)
Linum sulcatum (grooved yellow flax)

Lithospermum incisum (fringed puccoon)
Petalostemum purpureum (purple prairie clover)
Psoralea tenuiflora (scurfy pea)
Wulfenia bullii (kitten tails)

REMNANT INDIANA PRAIRIES

Like its neighboring states, Indiana has lost most of its prairies. What is left are bits and scraps scattered in old settler cemeteries, along railroad rights-of-way and in tracts of varying size that are of low agricultural value. The following list of remnant prairies in Indiana is not necessarily complete, since there are undoubtedly others that are still to be found.

Sand Prairie Remnants. The 121 ha (300 acre) Hoosier Prairie, a complex mosaic of black oak savanna, dry prairie, wet acid sand prairie and marsh, west of Griffith, Lake County, is a fine example of Indiana sand prairies on the Calumet plain. Over 300 species of native flowering plants have been found on the tract, including the prairie parsley (Polytaenia nuttallii), three species of gentians, and various species of orchids. Due to the persistent efforts of relatively few conservationists, it is now being purchased by the state of Indiana and will be managed as Indiana's first prairie preserve.

The 20 ha (50 acre) Clark Prairie, a combination of black oak savanna, dry prairie, wet alkaline sand prairie, and marsh, near Lake Michigan west of Gary, Lake County, is interesting in that it probably contains the best remnant of alkaline sand prairie left in Indiana, with numerous terrestial orchids, fringed gentians and lilies. In addition, the open lagoons in the area contain rich populations of both white and yellow water lilies (Nymphaea tuberosa and Nuphar advena). Moreover, the dune ridges are some of the last refuges for paper birch (Betula papyrifera), jack pine (Pinus banksiana) and buffalo berry (Shepherdia canadensis) in northwestern Indiana.

The Hammond Prairie, a 40 ha (100 acre) tract on the eastern outskirts of Hammond, Lake County, is a complex mixture of black oak savanna, dry sand, and wet acid sand prairies, and marsh. In late spring and early summer, the prairie is a riot of color, especially if previously burned, with much Indian paint brush (Castilleja coccinea), hoary puccoon (Lithospermum canescens), and prairie phlox (Phlox pilosa). Many species of orchids are common on the prairie, including the yellow lady's slipper orchid (Cypripedium calceolus) and showy lady's slipper (C. reginae), grass pink orchid (Calopogon pulchellus) and tubercled orchid (Habenaria flava herbiola).

Some of the best dry and wet acid sand prairie remnants are to be found along railroad rights-of-way in Starke, Porter, Jasper and LaPorte counties. Many of these prairies are certainly virgin, and typical prairie grasses, such as little and big bluestem, Indian grass, blue-joint grass, prairie cord grass and switch grass, mingle with lead plant, white wild indigo (Baptisia leucantha), flowering spurge (Euphorbia corollata), Culver's root (Veronicastrum virginicum), marsh phlox (Phlox glaberrima interior) and golden Alexanders (Zizia aurea).

Scattered through the sand country on the dunes and ridges are old settler cemeteries, with dry sand prairies and black oak savannas. Because of constant mowing, many are somewhat degraded. With cessation of mowing, a few could be restored to their former condition. In addition to the dominant little bluestem, butterfly weed (Asclepias tuberosa), sky-blue aster (Aster azureus), western sunflower (Helianthus occidentalis), rough blazing star (Liatris aspera) and prairie willow (Salix humilis) are common components of these cemetery prairies.

A certain amount of dry prairie and black oak savanna exists within the Indiana Dunes State Park and the Indiana Lakeshore National Park in Porter County. However, becasue of the lack of fires for decades, much of this prairie has been subverted by the rampant growth of black oak, so what was probably black oak savanna is now black oak woods. Certain sections are now being burned in an effort to reverse this trend.

Black Silt-Loam Prairie Remnants. Because of their rich agricultural value, very few remnants of these types of prairie survive. Some of the best remnants in Indiana are still to be found along certain sections of railroad rights-of-way in central Benton and southern Newton counties. Some degraded remnants of the Valparaiso Moraine prairies are found along railroad tracks in western Lake County. In northern Kosciusko County in eastern Indiana there is a small degraded remnant of the Turkey Prairie outlier.

One of the finest examples of mesic black soil prairie on the Valparaiso Moraine is found in the German Methodist Cemetery in western Lake County. Prairie gentians (Gentiana puberula), prairie lilies (Lilium philadelphicum andinum), purple prairie clover (Petalostemum purpureum), Leiberg's panic grass (Panicum leibergii) and alum root (Heuchera richardsonii) are just a few of the prairie forbs and grasses found in a sward of prairie dropseed. The prairie appears to be virgin and stands approximately six inches above the surrounding eroded fields. Unfortunately, it is not protected and diggings from the grave sites are being dumped onto the prairie.

The Granville Cemetery prairie, overlooking the Wabash River in central Tippecanoe County and presently being managed, contains various prairie plants, including side-oats grama grass, lead plant, false boneset (Kuhnia eupatorioides corymbulosa), New Jersey tea (Ceanothus americanus) and yellow cone flower (Ratibida pinnata). It is the only remnant known of the Wea prairie outlier.

Around the tombstones in the old settler Jackson Prairie Cemetery in western Steuben County in extreme northeastern Indiana, grow side-oats grama grass, big and little bluestem, Indian grass, Western sunflower (Helianthus occidentalis), Illinois tick trefoil (Desmodium illinoense) and yellow coneflower, remnants of the Jackson Prairie outlier. It is presently being mowed, but with proper management could return to a more natural condition.

Along the railroad right-of-way in central Tipton county south of Kokomo is a very rich prairie, a relic of Indian Prairie outlier. One of the eastern-most stations for the purple prairie clover (Petalostemum purpureum), it contains nearly fifty prairie species.

Dry Gravel Hill Prairie Remnants. Only one remnant of this rare type of prairie has been found in Indiana. Found on a gravel knoll overlooking Wea Creek, a tributary of the Wabash River in Tippecanoe County, it is no more than 0.1 ha (.25 acre) in size. Various grasses, including side-oats grama, hairy grama (Bouteloua hirsuta), porcupine grass, together with Western wall flower (Erysimum asperum), lead plant, false toadflax (Commandra richardsiana), purple prairie clover and fringed puccoon (Lithospermum incisum) are a few of the species still present in this tiny remnant.

Formerly, prairie satin grass (Muhlenbergia cuspidata), scurfy pea (Psoralea tenuiflora) and Tennessee milkvetch (Astragalus tennesseensis) were found in the vicinity, and presumably were collected on the more extensive prairie that once existed there (Deam 1940, Stuart 1902). The original prairie must have covered a substantial portion of the gravel ridge running along Wea Creek, but gravel mining operations have almost completely eliminated sections of the ridge. In addition, the lack of prairie fires in modern times has enabled the adjacent forest to penetrate prairie portions of the hill.

CONCLUSION

Although the prairies of Indiana in pre-settlement times occupied a relatively small area as compared to the area occupied by prairie in the states to the west, they are interesting because they occupied a region where the vegetation was transitional or ecotonal. Here on the plains of Indiana in what is considered a forest climate, prairie and deciduous forest mingled in a complex mosaic of trees and grass. It is important that the remnants of these interesting plant communities be preserved and studied in order to better understand the nature of the tall grass prairie.

LITERATURE CITED

Benninghoff, W. S. 1963. The prairie peninsula as a filter barrier to post-glacial plant migration. Proc. Ind. Acad. Sci. 73:116-124.

Bliss, L. C., and S. W. Cox. 1964. Plant community and soil variation within a northern Indiana prairie. Am. Midl. Nat. 72:115-128.

Brown, John. 1884. The Kankakee River, its peculiarities, its marsh lands and islands. Lake County, Indiana, 1884: An account of the semi-centennial celebration of Lake County, September 3 and 4 with historical papers and other interesting records prepared for this volume. Lake County Star Office, Crown Point, Ind. p. 184-187.

Deam, Charles. 1940. Flora of Indiana. Dept. of Conserv., Indianapolis, Ind. 1236 p.

Dick-Peddie, W. A. 1955. Presettlement forest types in Iowa. Ph.D. dissertation. Ia. State Univ. 76 p.

Finley, Dean, and J. E. Potzger. 1951. Characteristics of the original vegetation in some prairie counties of Indiana. Butler Univ. Bot. Stud. 10:114-118.

Flint, Thomas. 1826. From recollections of the last ten years, based on occasional residences and journeyings in the Valley of the Mississippi. In: H. Lindley, ed., Indiana as seen by early travelers. Indianapolis. 445 p.

Friesner, R. C., and J. E. Potzger. 1946. The Cabin Creek Raised Bog, Randolph County, Indiana. Butler Univ. Bot. Stud. 8:24-43.

Peattie, Donald C. 1922. The Atlantic Coastal Plain element in the flora of the Great Lakes. Rhodora 24:57-70, 80-88.

Peattie, D. C. 1930. Flora of the Indiana Dunes. Field Mus. Nat. Hist., Chicago, Ill.

Rohr, Fred W., and J. E. Potzger. 1951. Forest and prairie in three northwestern Indiana counties. Butler Univ. Bot. Stud. 10:61-70.

Short, C. W. 1845. Observations on the botany of Illinois, more especially with reference to autumnal flora of the prairies. West. J. Med. Surg. New Ser. 3:185-198.

Starcs, Helene. 1961. Notes on vascular plants of the Cabin Creek Raised Bog. Proc. Ind. Acad. Sci. 71:305-319.

Stuart, W. 1902. Some additions to the flora of Indiana. Proc. Ind. Acad. Sci. 1901:282-284.

Swink, Floyd. 1974. Plants of the Chicago region. 2nd Ed. The Morton Arboretum, Lisle, Ill. 474 p.

Transeau, E. N. 1935. The prairie penninsula. Ecology 16:423-437.

Welch, W. H. 1929. Forest and prairie, Benton County, Indiana. Proc. Ind. Acad. Sci. 39:67-72.

A SURVEY OF WETLAND VEGETATION IN NORTH-CENTRAL IOWA

Gary K. Clambey and Roger Q. Landers

Department of Botany
North Dakota State University
Fargo, ND 58102
and
Department of Botany and Plant Pathology
Iowa State University
Ames, IA 50011

ABSTRACT

During the summer 1974, wetland vegetation was surveyed at 35 sites within the Des Moines glacial drift lobe of north-central Iowa. The wetlands ranged from small, seasonal ponds to large, relatively permanent lakes. Each plant community was sampled using a series of 1 m^2 quadrats placed at regular intervals. The wetland flora included 143 vascular plants, 3 bryophytes, and 2 charophytes. Among these were 99 wet meadow species, 22 emergents, 4 rooted species with floating leaves, 8 floating or suspended species, and 15 submergents. Phytogeographically, a fourth of these species have wide distributions, being either semi-cosmopolitan or occurring in some type of circumboreal pattern. Sixty percent of the species are limited to North America. The wetlands are marked by low diversity, a lack of ubiquitous species, and low interstand similarity. Consequently, a physiognomic classification based on vegetation zonation was used. Water analyses indicated the wetlands are relatively uniform. For these wetlands, primary determinants of plant community structure are suggested to be water depth, water permanency and the extent of water-level fluctuations, and biotic agents, including man.

INTRODUCTION

As the result of the Wisconsin glaciation, north-central Iowa, like parts of the adjacent Dakotas and Minnesota, had numerous wetlands. However, extensive drainage programs, beginning in the later part of the 19th century, have reduced wetland area to less than 10% of that found during the presettlement era (Shaw and Fredine; National Research Council, Committee on Agricultural Land Use and Wildlife Resources (1970). The remaining wetlands represent significant tracts of natural vegetation and wildlife habitat in a region otherwise largely developed for modern agriculture.

Because earlier summaries of wetland vegetation (Hayden 1942, Shimek 1948, Conard 1952) were relatively undetailed, we began a study in 1973 to assess the vegetation of selected wetlands, including observations on potentially significant environmental factors.

STUDY AREA

Thirty-five wetland sites, occurring in an area extending from approximately 42° 2'N to 43° 30'N and from 93° 30'W to 94° 50'W, were located by ground reconnaissance during the late summer of 1973 and the spring of 1974 (Clambey 1975). Sites chosen had to be inundated for at least part of the growing season, with wetland species constituting the major part of the plant community.

Lying entirely within the Des Moines lobe deposited during late Wisconsin glaciation, approximately 12,000 to 14,000 years B.P., much of the area is flat to gently rolling ground moraine, but it is interrupted by four belts of end moraine (Iowa Geological Survey 1955, Ruhe 1969). Palmquist and Bible (1974) reported the glacial drift is typically 30 to 45 m in thickness.

Drained by tributaries of the Mississippi River, the area is in an early stage of stream development with many sites lacking natural drainage (Iowa Geological Survey 1955, Walker 1966). By 1965, one-third to one-half of the Des Moines lobe had been drained by tiling and ditching (Oschwald et al. 1965).

The area has a subhumid, continental climate, with a mean frost-free period of 150 days (Oschwald et al. 1965). Mean annual precipitation is 760 mm, and three-fourths of the total comes during the period of April through September (U.S. Department of Commerce 1964). A significant element in long-term precipitation patterns is the year-to-year variability, including droughts of varying intensity (Reed 1941).

METHODS

During July and August 1974, the vegetation at each of the 35 sites was sampled by a series of 1-m^2 quadrats spaced uniformly along two or more randomly chosen compass lines extending from the edge of the wetland to the center. The wide range of wetland sizes, from a fraction of a hectare to well over 300 ha, made it impossible to use the same number of quadrats at each site. Instead, we recognized three size-classes (1 ha or less, between 1 and 10 ha, and greater than 10 ha) and used a different number of quadrats for each class (25, 100 and 200, respectively). Data were collected from 2,725 quadrats. Cover by aboveground portions was estimated within each quadrat for each species present.

Nomenclature for all vascular plants follows Fernald (1950). Nomenclature for the five species of bryophytes and charophytes follows Fassett (1957).

Triplicate water samples collected 0.1 m below the surface from each of 31 wetlands during mid-growing season were analyzed using a Hach Direct Reading Engineer's Laboratory and an Instrumentation Laboratory Model 245 pH meter. Measurements included pH, colorimetric tests for ammonia-nitrogen, nitrate-nitrogen, nitrite-nitrogen, orthophosphate, and iron, titrimetric tests for total alkalinity, phenolphthalein alkalinity, total hardness, calcium hardness, and chloride, and a turbidimetric test for sulfate.

RESULTS AND DISCUSSION

Floristics

During the study we found 148 species, including 143 vascular plants, 3 bryophytes, and 2 charophytes. Out of this group, 123 species appeared in one or more quadrats. The 148 species belonged to 89 genera within

46 families. Six leading families, Cyperaceae (26 species), Gramineae (16), Labiatae (10), Compositae (7), Polygonaceae (7), and Zosteraceae (7), made up half of the species complement. Genera having the largest numbers of representatives were Carex (12 species), Potamogeton (6), Scirpus (6), and Eleocharis (5).

Growth characteristics and habitat preferences were used to group species into five classes. Wet meadow species (Class 1) appeared predominantly in wet soils at the edges of wetlands. This was the largest class (99 species, 66.9% of the total species encountered). Emergents, those plants rooted in the soil but sending aerial portions above the water surface, constituted Class 2 (22 species, 14.9%). Rooted aquatic plants with floating leaves (Class 3) included 4 species (2.7%). Floating and suspended hydrophytes (Class 4) contained 8 species (5.4%), and Class 5, submerged hydrophytes, ranked third with 15 species (10.1%).

Phytogeography

To evaluate the phytogeographic affinities of Iowa wetlands, we determined the distribution patterns for the 142 angiosperm species from Muenscher (1944), Fernald (1950), Fassett (1957), and Gleason and Cronquist (1963). Ten species, termed "semi-cosmopolitan," are especially widely distributed, occurring in freshwater habitats throughout much of the world. Among these are three true hydrophytes: Ceratophyllum demersum (coontail), Potamogeton pectinatus (sago pondweed), and Spirodela polyrhiza (greater duckweed). The others are ruderals, such as Echinochloa crusgalli (barnyard grass) and Urtica dioica (stinging nettle), which appear in the wet meadow zone. Twenty-seven species occur in North America and Europe, 2 species are shared between North America and eastern temperate Asia, and 2 species extend from North America into South America. The largest group, 88 species, is limited to North America. Of those, 36 species are widely distributed in temperate North America. Most of the remainder are localized in the northern and eastern sectors of the continent. The floristic affinity of the Wisconsin drift area with northerly regions had been noted earlier by Hayden (1942).

Phytosociology

Compared to many terrestrial communities, a notable aspect of these wetland plant communities was low species diversity. The average number of species per site ranged from 15.5 for small wetlands to 28.3 for intermediate-size wetlands and 32.6 in large wetlands. Amplifying this picture of limited diversity is the concentration of dominance, or lack of species equitability. Depending on the site, from 1 to 5 species constituted 50% or more of the relative cover, while many species were minor components. However, it would be a mistake to conclude that there is little site-to-site variation in the vegetation. Using relative cover values, percentage similarity was calculated for every possible stand-pair (Gauch and Whittaker 1972). Of the 595 possible stand-pairs, only 10 had similarity values greater than 50%, and 444 had less than 20% similarity.

Another indication of community variability comes with the comparison of dominant species, which have often been used as a basis for classifying communities (Whittaker 1962). For the 35 stands, there were 24 species which were leading dominants in at least one wetland. A total of 41 species ranked fourth or higher at least once.

There were no ubiquitous species common to all wetlands. Sagittaria latifolia (arrowhead), an emergent occurring in 29 of the 35 sites, had the highest presence value, 82.9%. The only other emergent species with a presence value greater than 50% was Scirpus fluviatilis (river bulrush). Polygonum coccineum (marsh smartweed), a wet meadow species, had a presence value of 65.7%. Only two other wet meadow species, Leersia oryzoides (rice cutgrass) and Phalaris arundinacea (reed canary grass), occurred in more than half of the wetlands. Spirodela polyrhiza and Lemna trisulca (star-leaved duckweed) were the most widespread floating species (42.9 and 40.0%). Of the submergents, two pondweeds, Potamogeton pusillus (narrow-leaved pondweed) and P. pectinatus had the greatest presence values (42.0 and 37.1%). None of the three rooted species with floating leaves (Nuphar variegatum, yellow pond lily; Nymphaea tuberosa, white pond lily; Potamogeton natans, broad-leaved pondweed) occurred in more than 2 sites.

Curtis and Greene (1949) noted the same lack of ubiquitous species in Wisconsin prairie, and they concluded:

> "Less than 1 percent of the total species were found in 80 percent or more of the stations, while over 62 percent of the species occurred in only 20 percent or less of the stations . . . . In general terms, the shape of the presence diagrams so far published indicates that most 'associations,' regardless of the magnitude of their conception, contain only a few species which are regularly or even usually present. Rather, they are mixtures of many species, most of which occur rarely or occasionally."

Consequently, we classified the wetlands physiognomically, using vegetative zones as in the system of Stewart and Kantrud (1971). Four classes were recognized.

Class I. Wet meadow species were dominant throughout the basin. The one example of this type occurred in an uncultivated low prairie. There was a predominance of graminoid cover, contributed largely by Spartina pectinata (prairie cordgrass), with lesser amounts of Calamagrostis canadensis (blue-joint grass), Phalaris arundinacea, two species of Carex (sedge), and Eleocharis palustris (spike-rush). The leading forb was Polygonum coccineum. The soil was wet for most of the growing season, but standing water disappeared by late spring. The scarcity of this type of wetland is due to the ease with which drainage and cultivation can be implemented.

Class II. Dominant plant cover throughout the central vegetation zone consisted of emergent species. Standing water usually persisted until midsummer. Fourteen wetlands were in this category. Among the characteristic emergents were Alisma triviale (mud plantain), Sagittaria latifolia, Scirpus fluviatilis, S. validus (softstem bulrush), Typha latifolia (broad-leaved cattail), and T. glauca (hybrid cattail). As with most wetlands, species composition of the wet meadow zone was quite variable.

Five wetlands, which had experienced intermittent cultivation during dry years, were included in this group. In addition to the characteristic emergents noted above, common wet meadow species were Eleocharis calva (spike-rush), Leersia oryzoides, and Polygonum coccineum. Typically the marsh periphery was covered by Hordeum jubatum (squirrel-tail grass). Rumex crispus (curly dock), and three species of Juncus (rush). The resiliency of such wetlands must be attributable to a store of resistant propagules.

Also included in Class II was one large marsh undergoing an artifical drawdown for waterfowl management. The resultant plant community consisted largely of Bidens spp. (stick-tights), Polygonum lapathifolium (nodding smartweed), and Scirpus validus. By late summer, these species were laced together by extensive growths of Cuscuta maculata, forming an almost impenetrable growth. Clones of Typha, Scirpus fluviatilis, and Sparganium eurycarpum (bur-reed) established prior to drawdown persisted. In areas not dry until midsummer, plant cover consisted largely of seedlings of Sagittaria latifolia and Scirpus validus.

Class III. These wetlands, which are relatively permanent bodies of water, were characterized by an interspersion of emergent and submergent species, but lacking a discrete submergent zone. In these 7 wetlands, the total cover of wet meadow species was low relative to that of emergents and submergents. Species of Sagittaria, Scirpus, and Typha, along with Sparganium eurycarpum, often dominated the emergent zone. Phragmites communis var. berlandieri (reed grass), described by Conard (1952) as typical of Iowa marshes, was abundant in only one site. Floating and suspended species, e.g., Drepanocladus sp. (aquatic moss), Lemna minor (duckweed), L. trisulca, Riccia fluitans (aquatic liverwort), Spirodela polyrhiza, Utricularia vulgaris (bladderwort), and Wolffia columbiana (watermeal), often formed a significant element in Class III and IV wetlands. These species occurred in sheltered open-water areas as well as amongst emergent vegetation, frequently forming a continuous "understory" on the water surface. Ceratophyllum demersum, Chara sp. (stonewort), Myriophyllum exalbescens (water milfoil), Najas flexilis (naiad), Potamogeton pectinatus, P. pusillus, and P. zosteriformis (flat-stem pondweed) were common submergents.

Class IV. Wetlands with a distinct submergent zone in part of the basin comprised this group. These were the deepest, most permanent wetlands, with maximum water depths from 1 to 2.5 meters. With the exceptions of the distinct submergent zone and often greater relative cover contributed by submergent species, the descriptions for Class III wetlands are also pertinent here. The same submergent species were abundant, and, in the deepest water, Ceratophyllum demersum and Potamogeton pectinatus were dominant. The often recognized zone of floating-leaved, anchored hydrophytes between the emergent and submergent zones (Sculthorpe 1967) was either absent or very discontinuous in our sites.

Water Chemistry

Although the physical water regimes of these wetlands differed greatly, there were not large differences in water chemistry. Most of the wetlands were slightly basic, with pH values from 7.0 to 9.8. Alkalinity averaged 150 ppm $CaCO_3$. The main source of alkalinity and the predominant anion is the bicarbonate ion (Bachmann 1965). Average hardness was 170 ppm $CaCO_3$, the predominate cation being calcium. The mean sulfate concentration was 22 ppm, and the mean chloride level was 12 ppm. None of the wetlands would be considered saline. Iron averaged 0.09 ppm, and, in 10 instances, no iron was detected. Concentrations of nitrogen and phosphorus were variable but quite high, as compared to world averages for bodies of freshwater (Reid 1961). Measurement of nitrate-, nitrite-, and ammonia-nitrogen indicated a significant portion of the available nitrogen existed in the reduced form.

CONCLUSIONS

Working in broader, geologically more diverse areas, Stewart and Kantrud (1971) and Moyle (1945) found differences in water chemistry accounted for much of the variation in aquatic plant communities. For our 35 sites the chemical differences were slight, and the primary determinants of wetland community structure are suggested to include water depth, water permanency, the extent and frequency of water-level fluctuations, and impacts of biotic agents, including muskrats, waterfowl, insects, pathogens, and man.

Because remaining wetlands are remnants of natural vegetation and wildlife habitat in an intensively developed state, their preservation is warranted. Most of the large and intermediate-sized wetlands surveyed are already controlled by the Iowa Conservation Commission. The fate of many small wetlands might be quite different. Effects on cropping of adjacent fields and potential productivity mean landowners are often not receptive to wetland acquisition and preservation. The best hope comes where such areas are part of a larger area, not presently cropped, which can be purchased and preserved as an intact unit. For instance, five of the sites occurred within an uncultivated low prairie. Continued identification and acquisition of such areas is crucial to preserving a small portion of Iowa's natural heritage.

ACKNOWLEDGEMENTS

Work of the senior author was supported by an Iowa State University Research Foundation Fellowship, a National Science Foundation Traineeship, and an Iowa State University Dissertation Research Assistantship.

LITERATURE CITED

Bachmann, R. W. 1965. Some chemical characteristics of Iowa lakes and reservoirs. Proc. Iowa Acad. Sci. 72:238-243.

Clambey, G. K. 1975. A survey of wetland vegetation in north-central Iowa. Ph.D. Thesis. Iowa State University, Ames. 207 p.

Conard, H. S. 1952. The vegetation of Iowa. State Univ. Iowa Stud. Nat. Hist. 19(4). 166 p.

Curtis, J. T., and H. C. Greene. 1949. A study of relic Wisconsin prairies by the species presence method. Ecology 30:83-92.

Fassett, N. C. 1957. A manual of aquatic plants. Univ. Wisc. Press, Madison. 405 p.

Fernald, M. L. 1950. Gray's manual of botany, 8th ed.

D. Van Nostrand, New York. 1632 p.

Gauch, H. G., Jr., and R. H. Whittaker. 1972. Comparisons of ordination techniques. Ecology 53: 868-875.

Gleason, H. A., and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. Van Nostrand, Princeton, N.J. 810 p.

Hayden, A. 1942. A botanical survey in the Iowa lake region of Clay and Palo Alto Counties. Iowa State J. Sci. 17:277-415.

Iowa Geological Survey. 1955. Quality of surface waters of Iowa, 1886-1954. Iowa Geol. Sur. Water Supply Bull. No. 5. 351 p.

Moyle, J. B. 1945. Some chemical factors influencing the distribution of aquatic plants in Minnesota. Am. Midl. Nat. 34:402-420.

Muenscher, W. C. 1944. Aquatic plants of the United States. Comstock, Ithaca, N.Y. 374 p.

National Research Council, Committee on Agricultural Land Use and Wildlife Resources. 1970. Land use and wildlife resources. Nat. Acad. Sci., Wash., D.C. 262 p.

Oschwald, W. R., F. F. Riecken, R. I. Dideriksen, W. H. Scholtes, and F. W. Schaller. 1965. Principal soils of Iowa. Iowa State Univ. Agr. Expt. Sta. Spec. Rep. 42. 76 p.

Palmquist, R. C., and G. Bible. 1974. Bedrock topography beneath the Des Moines Drift Sheet, north-central Iowa. Proc. Iowa Acad. Sci. 81: 164-170.

Reed, C. D. 1941. Climate of Iowa. Pages 862-872 in: U.S. Department of Agriculture, Climate and man. U.S. Government Printing Office, Wash., D.C.

Reid, G. K. 1961. Ecology of inland waters and estuaries. Reinhold, New York. 375 p.

Ruhe, R. V. 1969. Quaternary landscapes of Iowa. Iowa State Univ. Press, Ames. 255 p.

Sculthorpe, C. D. 1967. The biology of aquatic vascular plants. Edward Arnold, London. 610 p.

Shaw, S. P., and C. G. Fredine. 1956. Wetlands of the United States: Their extent and their value to waterfowl and other wildlife. U.S. Fish Wildl. Ser. Circ. 39. 67 p.

Shimek, B. 1948. The plant geography of Iowa. State Univ. Iowa Stud. Nat. Hist. 18 (4). 178 p.

Stewart, R. E., and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. U.S. Bur. Sport Fish. Wildl. Res. Pub. 92. 57 p.

U.S. Department of Commerce. 1964. Climatography of the United States, No. 86-11. U.S. Superintendent of Documents, Wash. D.C. 84 p.

Walker, P. H. 1966. Postglacial environments in relation to landscape and soils on the Cary Drift, Iowa. Iowa State Univ. Agr. Expt. Sta. Res. Bull. 549. 37 p.

Whittaker, R. H. 1962. Classification of natural communities. Bot. Rev. 28:1-239.

PRAIRIE VEGETATION IN NATIONAL PARKS, MIDWEST REGION

Roger Q. Landers, Jr.

Department of Botany and Plant Pathology
Ames, Iowa 50011

ABSTRACT

Prairie remnants and areas replanted to prairie species in Midwest National Parks are discussed.

INTRODUCTION

The vast prairie landscape, which once was characteristic of much of the Midwest, particularly west of the Mississippi River, has been transformed in slightly more than a century into one of the world's most productive agricultural regions. The vastness, once unbroken except for occasional trails, villages and patches of trees, is interrupted today in every long distance view by highways, high lines, or high rise apartments, essential features of our civilization. But the prairie species persist, if only a fraction of the original biomass, in enclaves created by variations in the land surface and through deliberate actions by humans.

Much has been written about the extent of the original prairie in North America. Occasionally applied to the entire Grassland Formation, the term "Prairie" is more often restricted in use to the eastern half of the grassland where it was first used by French explorers along the Mississippi River. I will use it in the more restricted sense to cover grasslands from Canada to the Gulf of Mexico usually bordering on Deciduous Forest to the east and short grassland to the west, realizing, however, that the boundaries are dynamic. The Prairie Peninsula extends eastward into Indiana, where it ceases to maintain connected units, but extends even further as oak openings into Ohio.

Prairie soils support the heart of North American agriculture. Unlike the forest soils, formed with an accumulation of organic matter on top the ground, the prairie soils formed with organic matter distributed through the soil profile as the result of rapid turnover of fibrous root systems of grasses and abundant nitrogen fixation by the root nodule bacteria of legumes. Although it is the grass family that characterizes the prairie from a traditional point of view, it is the array of colorful flowers blooming from spring to fall which often brings the visitor back again and again to see the flower gardens of the prairie. The prairie soils, more than any other characteristic, led to the downfall of prairie. Prairie species, adapted to eons of extremes of moisture, temperature, grazing, and fire, were no match for the plow. What could survive the extremes of mid continental climate would not survive the technology of modern productive agriculture except as small remnants.

This report summarizes observations made during summer 1975 on prairie remnants and established prairie species in National Parks and Monuments in the Midwest Region from Indiana to western Nebraska and Minnesota to southern Missouri. It is a status report approximating management success in achieving objectives dealing with prairie vegetation in the park landscapes (Landers 1975). Most of the areas are not within the top ten most popular and well known national parks; in fact I imagine few, if any of you, have visited half the areas. They have little in common except in the connection with the regional vegetation once prominently prairie. How the natural vegetation fits into the scheme of things within each park is a central question in its management.

PIPESTONE NATIONAL MONUMENT

Pipestone National Monument in southwestern Minnesota consists of 283 acres, with well over half consisting of original prairie. Scattered shrubby growth was depicted all along the quartzite outcropping in George Catlin's 1838 painting; however today there is extensive growth of bur oak, American elm, and other woody plants spreading out from the rocky points. If the prairie were as closely grazed and trampled as is suggested in his painting, it has, indeed, done well on its own. Fire has been used in the management program since 1973 probably in response to the apparently beneficial impact of a wildfire in 1971 which burned along Pipestone Creek. Approximately 80 acres were cultivated as recently as 1956 when the land was added to the park. Today it appears like prairie from a distance but its composition is mainly a mixture of early successional species and a scattering of the prairie originals such as wild strawberry. A healthy prairie situation in general is true for the main area of the Monument; however, the continued use of fire is recommended for its management.

HERBERT HOOVER NATIONAL HISTORICAL SITE

Herbert Hoover National Historical Site in eastern Iowa was started from scratch as far as prairie species are concerned. Approximately 76 acres of formerly cultivated ground were planted to a mixture of tall grasses in 1971. Although it is probable that Bluestem Prairie (Küchler 1964) once occupied the site before the town of West Branch was established, it is likewise probable that the prairie had been transformed into farmland before the boyhood days of Herbert Hoover. Thus, the appearance of prairie is not an authentic part of the scene being reconstructed in honor of Herbert Hoover; it is primarily useful as a natural maintenance feature. Burning may not be practical because of the proximity to Interstate 80 and West Branch. Mowing in early fall one year in four may be substituted for fire. Studies are underway to add forbs to the present well-established grasses and to examine means of controlling weedy growth in portions where grasses were poorly established.

EFFIGY MOUNDS NATIONAL MONUMENT

Effigy Mounds National Monument in northeast Iowa overlooking the Mississippi River has little patches of original prairie amounting to an acre or less on severe south facing slopes, with scattered chinkapin oak and abundant eastern red-cedar established as old, often gnarled and fire scarred trees along the bluff edges. Trees are closing in on these areas as well as in formerly cultivated flatlands away from the bluffs. Fire naturally kept the bluffs sites open in the past; however this is being done today by limited clearing of woody growth as much to maintain a view of the river as to retain the prairie species. Trees are being allowed to dominate formerly cultivated areas.

HOMESTEAD NATIONAL MONUMENT

Homestead National Monument, Beatrice, Nebraska, consists of 160 acres in the original 1853 homestead of Daniel Freeman with approximately two-thirds prairie and one-third timber both then and now. Two acres, one quarter mile away containing a brick school house, have recently been added to the monument. At least half of the school house ground is a mowed but never plowed remnant of original prairie. Apparently all the prairie land on the original homestead was cultivated. Very few details are available concerning the reestablishment of the prairie on the main unit, but superintendents' notes reveal a steady improvement from 1937 when efforts were begun to replant badly eroded slopes to prairie vegetation. A "good establishment" was obtained from the 1937 planting which included the use of seed and some prairie sod. This represents the earliest known reestablishment of prairie on cultivated land in the Midwest. Today woody plant invasion is occurring along the edges and low ground; however, on the upper slopes to the south, the best example of prairie reestablishment in Midwest parks can be seen. On poorly drained ground near the creek, prairie reestablishment was less successful.

SCOTTS BLUFF NATIONAL MONUMENT

Scotts Bluff is an impressive feature of the surrounding plains rising 800 feet above the valley floor in western Nebraska. The vegetation consists of at least three groupings: the moderately dense, short or medium tall grassland designated Wheatgrass-Needlegrass, the Sage-Bluestem Prairie, and the eastern Ponderosa Forest (Küchler 1964). Grazing by native animals and fire undoubtedly were important in their effects upon the vegetation of this region. In the vicinity of Scotts Bluff people in large numbers passing through during the 19th Century needed grazing for their livestock and wood for their fires and constructions. Cattle grazing persisted on Scotts Bluff perhaps well after establishment of the monument in 1919. It was reopened temporarily to grazing during WW II. Burning, mowing or grazing have not been used in maintaining prairie vegetation in recent years. Despite a scattered increase in woody plants in recent decades, it appears that the prairie vegetation is in no danger of being overgrown. Some recent acquisitions, once cultivated, are being replanted to native grasses and forbs with fair success.

AGATE FOSSIL BEDS NATIONAL MONUMENT

The Agate Fossil Beds is largely intact Wheatgrass-Needlegrass Prairie with open floodplain meadow along the Niobrara River in western Nebraska in total amounting to approximately 1970 acres. Some weedy areas around recently acquired ranch buildings and fields are the only highly disturbed vegetation areas. It is the most unmodified from the original of any of the areas among Midwest parks, requiring nothing but the most minimum of maintenance.

FORT LARNED HISTORICAL SITE

Fort Larned National Historic Site, Larned, Kansas, is almost completely replanted to native grasses. The original vegetation would have been Bluestem-Grama Prairie on higher ground and Floodplain Forest and Savanna immediately next to the Pawnee River. The partially restored fort has scattered trees and mowed lawn around the buildings with the appearance of closely mowed hay fields in the distance. In the 44-acre detached area a few miles southwest containing tracks of the Santa Fe Trail, grazing has resulted in a loss of many of the preferred species and a gain of species such as annual brome grasses and little barley. Grazing should be removed until some recovery of the original sod is achieved. Reestablishment efforts in other parts of the historical site have emphasized the use of blue grama and buffalo grass, and excellent detailed records have been kept since 1960 to document this progress. Taller species such as silver bluestem, Canada wild rye, big bluestem, little bluestem, and switchgrass would be expected to flourish if added to the previous planting.

WILSON'S CREEK NATIONAL BATTLEFIELD

Wilson's Creek National Battlefield near Springfield, Missouri, was the most difficult area to interpret regarding prairie vegetation. The question remains whether prairie was a small or large part of the site since the only historical comments are those of men "marching through park-like forests" to reach the summit of Bloody Hill. A few very old trees still remaining on rocky points of Bloody Hill suggest the original vegetation was a mosaic of Oak-Hickory Forest, Bluestem Prairie, and brushy or scattered tree "edge". No original prairie remnants were encountered; however, replanting of prairie species has been generally very successful. Not surprisingly, where unmowed, very vigorous invasion by woody plants is occurring. Fire has not been used in management of this site.

GEORGE WASHINGTON CARVER NATIONAL MONUMENT

The George Washington Carver National Monument, also west of Springfield, is equally difficult to interpret. A 19-acre pasture west of the visitor center is dominated by native prairie species. Mowed approximately once a year, this area appears to have substantially recovered from the short grass cover of a closely grazed pasture as it appears in 1952 photographs. An impressive herbarium here is an excellent resource for future evaluation of management not only of the prairie remnant but also of the fields and wooded stream vegetation.

NATIONAL LAKESHORE INDIANA DUNES

The natural setting of the dunes at the southern tip of Lake Michigan is a complex geological and biological maze that has fascinated ecologists since the beginning of this science. Thy physiography of the dunes creates a mantle of vegetation, complex in structure, composition, placement and in timing - from bare shifting sand to prairie, marsh, bog, and forest. Variations of the Bluestem Prairie are found in close proximity (Betz 1965). Prairie components are found as understory in black oak woodland, prairie marsh and dune sand habitat exist side by side, and all natural communities seem vulnerably close to human impact. Because of its importance as the birthplace of plant ecology in this country, if for nothing else, the Dunes is worthy of vigorous and enlightened management. Prairie vegetation is only a part of its significant features, and the proper integration of management procedures is essential to retain as much of the original landscape as possible with prairie vegetation a balanced part of the whole dune system.

CONCLUSIONS

The Midwest Park prairies are not well known, they have not been extensively used in research, but their potential value is very high. I describe them elsewhere as enclaves, not expansive prairie parks, although Agate Fossil Beds and portions of Scott's Bluff are rather expansive. I expect an interest in nature interpretation to grow so that our parks will be supporting more interpretive tours and building self-guiding trails with information on the natural setting. Their great value will be in providing the public with a better understanding of the natural prairie scene in association with the events which caused each area to be established as a national site. And perhaps too, they will provide us with information on the challenge of reconstructing prairie vegetation under a wide assortment of conditions. Not too many people had that in mind in 1937 when Homestead National Monument was established. Today, reconstruction of prairie is happening all over.

ACKNOWLEDGEMENTS

This pleasant assignment was made possible by a grant from the National Park Service, Midwest Region and arrangements with Iowa State University.

LITERATURE CITED

Betz, Robert. 1965. Prairie plants of the Chicago Region. Morton Arboretum, Lisle, Illinois.

Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. Amer. Geographical Soc. Special Publ. No. 36.

Landers, Roger Q., Jr. 1975. A report on the status and management of native prairie areas in national parks and monuments in the midwest region. Submitted to National Park Service, Omaha, Nebraska.

A PLANT SPECIES INVENTORY AND EVALUATION OF SOME PRAIRIE REMNANTS IN WAUKESHA COUNTY, WISCONSIN

Trelen Wilson

Milwaukee, Wisconsin 53202

ABSTRACT

A survey of 57 collection sites covering 75 ha indicates that at least 243 flowering species of indigenous prairie plants still grow within a 265 km^2 area in southwestern Waukesha County, Wisconsin. Demographic trends, over-grazing, lack of burns, genetic isolation, and the absence of certain inter-organismal relationships jeopardize the future of many of these species as well as the communities in which they live.

INTRODUCTION

This paper is a preliminary floristic study of the prairie remnants of Waukesha County, Wisconsin. From November 1972 through October 1975 I took photos and collected specimens of 243 flowering plant species growing in southwest Waukesha County. All 243 were identifiable as species native to North American prairies and oak savannas. The 243 species came from 57 collection sites, of which 33 were actual remnants and 10 were abandoned lands going through early prairie succession. The other 14 sites were isolated stands of individual species removed from the main body of any remnant by at least 50 m. There exist at least 30 more remnants in the area, but because some had no new or significant species, and others were on private lands to which I was unable to gain access, these additional remnants were not included.

Waukesha County in in southeastern Wisconsin. It is bisected by 43° N latitude and 88° 20' W longitude. The actual study area is located in the southwest corner of the county. It covers all of Eagle and Mukwonago Townships, the southern parts of Ottawa and Genesee Townships, and the western part of Waukesha Township (Fig. 1).

Topography and Glacial History. For the most part, the Wisconsin Ice Sheet of 10,000 years ago determined the physiography of the study area. The melting glacier left behind pitted and unpitted outwash plains, rolling ground moraines, and the extremely hilly Kettle Moraine.

On the west end of the study area, orientated in a north-south direction, there is a band of poorly drained outwash plain which in presettlement time had much wet prairie (Fig. 1). Rising up from the east edge of this plain is the Kettle Moraine. Only 300-900 m wide, the Kettle Moraine is an extremely irregular terrain formed where two lobes of the Wisconsin Ice Sheet collided. Becuase it is so irregular, much of the moraine has never been plowed. Consequently, it is a refuge for many "goat" prairies and oak opening remnants.

East of the Kettle Moraine is another outwash plain. This outwash is well drained and has pits and terraces. It once contained the county's largest prairie, the 15 km^2 Eagle Prairie.

The remaining eastern half of the study area is mostly rolling ground moraine. A recent interpretation of the Official U.S. Land Survey of 1836 indicates that oak savanna was the dominant community type here (Schwarzmeier and Johnson 1975). At the extreme east end of the study area the rolling hills drop into the flat flood plain of the Fox River.

Running along the entire southern border of the study area is the post-glacial Troy Valley. In preglacial times it was over 150 m deep, but today it is almost completely filled in with glacial till. A steep, gravelly bluff outlines the north wall of the former valley. At the bottom lie many lakes and marshes, while higher up, covering the bluff, are numerous "goat" prairies.

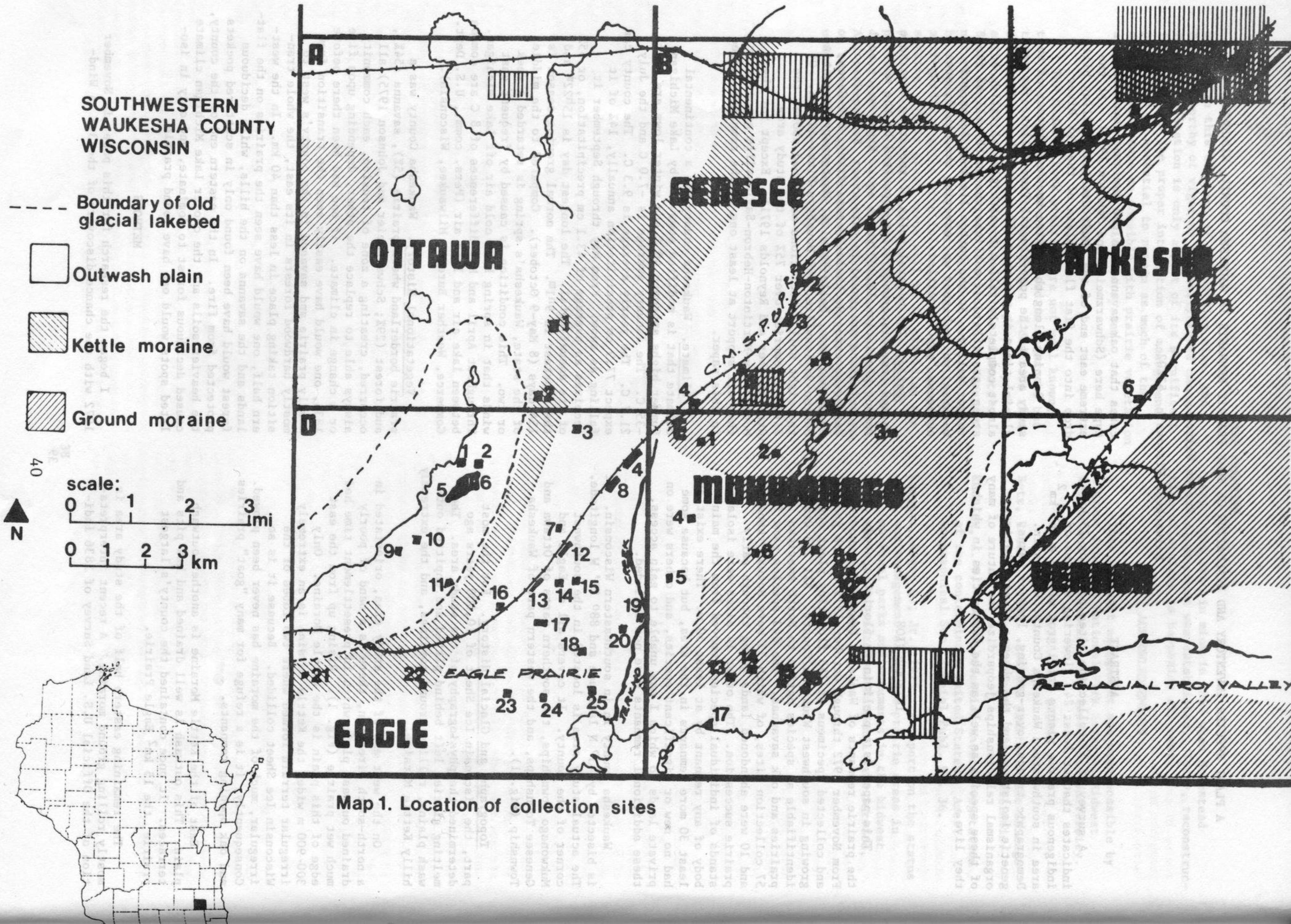
Soils. The mineral soils of the study area have formed from clacareous drift deposited by the most recent glaciation 10,000 years ago. Eight major soil associations are found in this area: Rodman-Casco, Warsaw-Lorenzo, Hochheim-Theresa-Miami, Fox-Casco, Boyer-Oshtempo, Pella-Knowles, Montgomery-Martinton-Hebron-Saylesville, and Houghton-Plams-Adrian. Of the eight soil associations mentioned above, the first 3 comprise over 75% of the study area (Steingraeber and Reynolds 1971). Except for the Montgomery-Martinton-Hebron-Saylesville association they all support at least one of the remnants listed in this paper.

Climate. Waukesha county has a continental climate that is modified somewhat by Lake Michigan. Summer highs approach 40 C and winter lows are near -35 C. The January average is -7.0 C and the July, 21.7 C. The yearly average is 9.3 C. The county can expect 77.9 cm precipitation annually, 14% of it falling as snow. From May through September it receives an average of 43.1 cm precipitation, or 55% of its annual total. The longest day is 15^h22^m and the shortest is 9^h1^m. The normal growing season is 154 days (8 May-9 October). Compared to the middle of the state, Waukesha's spring is retarded a week or two. This condition is caused by frequent east winds that in spring blow cold air off Lake Michigan. Throughout April and May differences of 8 C are common between lake air and land air (Pers. comm., U.S. Dept. Commerce, Weather Bureau, Milwaukee, Wisconsin).

Vegetational History. Waukesha County was a prairie borderland where prairie (5%), savanna (54%), and forest (29%; Schwarzmeier and Johnson 1975) all occurred, creating a zone of tension, each community always able to replace the other, depending upon fire or a change in climate. If one had been there before 1836, one would have easily seen the transition from mostly prairie and savanna in the county's west to mostly hardwood forests in its east, the whole transition taking place in less than 40 km. In the western half, one would have seen the prairies on the flatlands and the savanna on the hills, while deciduous forest would have been found only in scattered pockets protected from fire. In the eastern end of the county, the heavier soils and the cooler Lake Michigan climate caused deciduous forest to dominate, and only in isolated spots would one have found prairie.

METHODS

I began the research for this paper in November 1972 with the chance discovery of the 3.3 ha Wind-



Map 1. Location of collection sites

works prairie. The following summer more data was gathered from weekly hikes along the Milwaukee Road railroad tracks between the city of Waukesha and the county's western edge. The total distance covered was 29 km. Also in 1973, I consulted with county naturalist, Jerry Schwarzmeier, for the location of other remnants. I located still others while simply driving around the countryside.

In 1974, I took over 600 photos and pressings to record the appearances of each new blooming species from three select remnants which I visited weekly. I chose the three particular remnants on the basis of their high quality and differing moisture regimes. The three were the 3.3 ha Windworks Prairie, which I chose because of its extensive dry prairie type, the Scuppernong Wet Meadow, because of its wet and wet-mesic prairie types; and the Doman remnant, because of its mesic and dry-mesic types. Despite its small half-hectare size, the Doman Remnant is one of the largest mesic remnants in the whole country. It is located on a terrace top in the former Eagle Prairie. Additional explorational hikes that summer produced still more remnants and more photographs adding significantly to the data.

In 1975, only three new species and no new territory were found.

KEY TO COLLECTION SITES

The key lists the location of each collection site, its prairie type, size, and quality. Locations are by section number and compass points, with "M" denoting the center of a section, along with prominent land features. (Locations are shown in Fig. 1). Approximate sizes are given in hectares. Grading of quality is somewhat subjective. "A" denotes high quality and means the remnant shows a diverse species composition, good balance among the species, and few or no alien invaders. "B" means the remnant is moderately degraded but still shows the basic makeup of a prairie community. "C" remnants are severely degraded. They are dominated by alien plant species and contain less than 10 different prairie species per 20 m^2. "C" also denotes early prairie-old field succession. "D" refers to isolated populations of one or two species.

A. Ottawa Township. T6N, R17E.
1. (26 SW) Portion "E-F" of Scuppernong Hiking Trail. 0.3 ha; "B-"; mesic, dry mesic.
2. (34 SE) E side of Hwy 67, S of Hwy ZZ.
0-0.1 ha; "D"; mesic.

B. Genesee Township. T6N, R18E.
1. (15 SE) CMStPP RR between Hwy D and Hwy ZZ.
1.4 ha; "B"; wet mesic, mesic, dry-mesic.
2. (21 S) E side of CMStPP RR.
0.0.1 ha; "C"; mesic.
3. (28 N) E side of CMStPP RR.
0-0.1 ha; "D"; mesic.
4. (31 SE) E side of CMStPP RR, just N of Hwy 59.
(0-0.1 ha; "C"; mesic.
5. (32 NE) E side of CMStPP RR.
0-0.1 ha; "C"; mesic.
6. (33 NE) E side of Dable Road, crest of hill.
0-0.1 ha; "B"; dry-mesic.
7. (34 SW) N side of Hwy X, bend in road.
0-0.1 ha; "D"; dry-mesic.

C. Waukesha Township. T6N, R19E.
1. (7 SW) CNW RR, 800 m W of Hwy TT.
0.3 ha; "B+"; wet-mesic.
2. (7 S) between CNW RR and CMStPP RR, 50 m W of Hwy TT.
0.2 ha; "C-"; dry-mesic; gravelly.
3. (8 W) S side of CMStPP RR on slight W slope.
0.1 ha; "B"; mesic.
4. (8 E) between CNW RR and CMStPP RR.
0.4 ha; "B+"; mesic.
5. (9 N) between CNW RR and CMStPP RR.
0-0.1 ha; "D"; mesic.
6. (33 S) N side of Soo Line RR, W side of Hwy XX.
0-0.1 ha; "D"; wet.

D. Eagle Township. T5N, R17E.
1. (4 SE) E side of bend in Scuppernong River.
0-0.1 ha; "C-"; wet-mesic.
2. (5 SW) 20 m E of a carr.
0-0.1 ha; "D"; wet.
3. (2 NE) 400 m W of Ulrickson Road in outwash kettle.
0.6 ha; "B"; dry, dry-mesic.
4. (1 S and E) 2.4 km along CMStPP RR.
3.0 ha; "B-"; wet, wet-mesic, mesic.
5. (9 NE) in Scuppernong Wet Meadow Scientific Area.
13.0 ha; "A"; wet, wet-mesic.
6. (10 NW) along and N of dirt access road.
2.0 ha; "B-"; wet-mesic.
7. (11 S) E side of Hwy 59, at section border.
0.1 ha; "B"; mesic.
8. (12 N) 600 m along CMStPP RR.
1.1 ha; "A"; wet, wet-mesic, mesic.
9. (17 NE) W of Hwy N.
2.5 ha; "B-"; mesic, successional refuge.
10. (16 NW) between Hwys GN and N.
10.0 ha; "A"; wet-mesic.
11. (16 S) E side of Hwy N, near Paradise Springs.
0-0.1 ha; "C"; mesic.
12. (14 N) 400 m along CMStPP RR, Beginning at Engebret Road to NE.
0.5 ha; "B-"; mesic.
13. (14 SW) 800 m along CMStPP RR, beginning at section border to NE.
1.0 ha; "B+"; mesic; some virgin, some successional.
14. (14 S) kettle in outwash.
0.3 ha; "B+"; mesic.
15. (14 SE) flat sandy area.
0.8 ha; "C"; dry-mesic.
16. (22 NE) W side of CMStPP RR.
0-0.1 ha; "C+"; mesic.
17. (23 W) N side of Hwy NN.
0-0.1 ha; "D"; dry-mesic; gravelly.
18. (23 SE) house construction on W side of Hwy NN.
0-0.1 ha; "D"; mesic.
19. (24 NE) oak opening on W side of Jericho Creek.
1.0 ha; "B-"; mesic.
20. (24 E) S side of Hwy NN.
0-0.1 ha; "D"; mesic.
21. (30 W) Eagle Oak Opening Scientific Area.
18.0 ha; "B-"; dry-mesic, dry.
22. (28 N) in oak opening, on ricky ridge top, in Old World Wisconsin.
0-0.1 ha; "C"; dry-mesic.
23. (27 E) Doman Remnant, 400 m E of Markam Road.
0.4 ha; "A-"; mesic.
24. (26 N) Eagle Town Dump Oak Opening.
13.0 ha; "B-"; mesic, dry-mesic.
25. (25 W) E side of Hwy NN.
0-0.1 ha; "B-"; mesic.

E. Mukwonago Township. T5N, R18E.
1. (6 E) W side of Hwy E at crest of hill. 0-0.1 ha; "D"; dry-mesic.
2. (4 W) W side of Schnitzler Road, on small knoll. 0.1 ha; "B-"; mesic.
3. (2 W) W side of Hwy 83, 400 m N of Hwy 1. 0-0.1 ha; "D"; mesic.
4. (7 E) W side of Hwy EE. 0-0.1 ha; "B-"; mesic.
5. (18 N) E side of Hwy E. 0-0.1 ha; "C+"; mesic.
6. (17 NE) E side of Beulah Road. 0-0.1 ha; "D"; wet-mesic.
7. (16 NE) W side of Hwy I, on crest of hill. 0-0.1 ha; "D"; dry.
8. (15 N) clearing in woods, 600 m E of Hwy I. 0.2 ha; "B+"; dry-mesic.
9. (15 S) 100 m N of bend in Stoneridge Drive. 0.1 ha; "B-"; dry-mesic.
10. (15 S) between Stoneridge Drive and Stonegate Drive. 0.1 ha; "B-"; dry-mesic.
11. (15 S) S of Stonegate Drive on ridge top. 0.1 ha; "A-"; dry.
12. (22 N) W of Mitchell Drive. 0-0.1 ha; "D"; mesic.
13. (29 N) E side of Beulah Road 0-0.1 ha; "C-"; mesic.
14. (29 NE) 100 m S of bend in Beulah Road 0.1 ha; "C"; dry-mesic.
15. (28 W) 500 m E of section border, 300 m N of Hwy 99, below bluff crest, next to woods, and near new house. 0.1 ha; "B"; dry-mesic.
16. (28 E) N side of Hwy 99, E side of ravine. 0.2 ha; "B-"; mesic, dry-mesic.
17. (31 NW) Windworks Prairie, 300 m S of Hwy 99. 2.1 ha; "A-"; dry, and 1.2 ha; "B"; wet.

CATALOGUE OF SPECIES

The catalogue is arranged alphabetically by scientific names. For grasses the nomenclature of Fassett (1951) was used. The names of the other flowering plants are according to Gleason and Cronquist (1963). Following most scientific names appears a colloquial name. After the names comes a statement of frequency, and in parenthesis a letter-number code. The code refers to the location of collection sites listed in Fig. 1 and listed in the key to collection sites.

The terms used in the frequency statement are "rare," "infrequent," "frequent," and "common." They pertain just to the area in this study, though often a species rare in Waukesha County is rare all over. "Rare" is used to mean just a few specimens appearing in one or two sites. "Infrequent" means appearing in less than half the remnants of one prairie type (wet through dry) or appearing in a number of prairie types but never in any single one more than 25% of the time. "Frequent" means in most all remnants of one prairie type or appearing in several prairie types but never in any single one more than 50% of the time. "Common" signifies the species grows in most remnants of most types and in some numbers along roadsides and fencerows. Usually only one collection site is given per species, but because some sites are unprotected, I have often listed alternate sites.

Instead of pressings, I recorded the appearance of most species on photographic slides with technical identifications done in the field and color close-ups to record the technical differences. At the time of this writing all specimens and photos are stored at the author's address.

Agropyron trachycaulum (Link) Steud. Slender wheatgrass. Infrequent; (B5).

A. trachycaulum, var. glaucum (Pease & Moore) Malte. Slender wheatgrass. Rare; (D5).

Agrostis hyemalis (Walt.) BSP. Early ticklegrass. Rare; (E11).

A. scabra Wild. Ticklegrass. Infrequent; (D5).

Ambrosia artemisiifolia L. Lesser ragweed. Common; (D6).

Amorpha canescens Pursh. Lead plant. Common; (D23).

Andropogon gerardi Vitman. Big bluestem. Common.

A. scoparius Michx. Little bluestem. Common.

Anemone canadensis L. Canada windflower. Frequent; (D4).

A. cylindrica Gray. Thimbleweed. Frequent; (E9).

A. patens L. Pasque flower. Frequent; (E18).

A. quinquefolia L. Wood anemone. Frequent; (E17); oak savanna species.

Antennaria canadensis Greene. Pussytoes. Infrequent; (E17).

A. munda Fern. Pussytoes. Infrequent; (E17).

A. neglecta Greene. Pussytoes. Frequent; (E17).

A. plantaginifolia (L.) Richards. Plantain-leaved pussytoes. Infrequent; (D13).

Apocynum androsaemifolium L. Spotted dogbane. Common; (B1).

A. cannabinum L. Indian hemp. Infrequent; (D5).

Arenaria stricata Michx. Rock sandwort. Infrequent; (E17).

Aristida oligantha Michx. Three-awned grass. Rare; (E15).

Asclepias amplexicaulis Sm. Blunt-leaved milkweed. Rare; (D8, E2).

A. purpurascens L. Purple milkweed. Rare; (E14).

A. incarnata L. Swamp milkweed. Infrequent; (D6).

A. syriaca L. Common milkweed. Common.

A. tuberosa L. Butterfly weed. Rare; (B2).

A. verticillata L. Whorled milkweed. Common; (E17).

Aster azureus Lindl. Sky-blue aster. Infrequent; (D5).

A. ericoides L. Heath aster. Common; (D5).

A. laevis L. Smooth aster. Infrequent; (D13).

A. novae-angliae L. New England aster. Frequent; (D6).

A. pilosus Willd. Frost aster. Common; (D23).

A. prenanthoides Muhl. Crooked-stemmed aster. Infrequent; (D6).

A. ptarmicoides (Nees) T. & G. White upland aster. Infrequent; (D14, D23).

A. puniceus L. Purple-stemmed aster. Infrequent; (D6).

A. sagittifolius Willd. Arrow-leaved aster. Infre-auent; (D23, D24).

A. simplex Willd. Marsh aster. Common; (D6).

A. unbellatus Mill. Flat-topped aster. Infrequent; (D6).

Aureolaria grandiflora (Benth.) Pennell. Yellow false foxglove. Rare; (E9); oak savanna species.

Baptisia leucantha T. & G. False wild indigo. Rare; (C1).

Besseya bullii (Eat.) Rydb. Kitten tails. Infrequent; (E11, E17).

Bidens coronata (L.) Britt. Tickseed sunflower. Infrequent; (D10).

B. vulgata Greene. Tall stick-tight. Frequent; (D5).

Blephilia ciliata (L.) Benth. Downy wood mint. Frequent; (D5).

Boltonia asteroides (L.) L'Her. Infrequent or rare; (D6).

Bouteloua curtipendula Michx. Side-oats grama. Frequent; (E17).

Bromus kalmii Gray. Prairie brome grass. Infrequent; (D5).

Cacalia atriplicifolia L. Pale Indian plantain. Rare; A2, B3).

C. tuberosa Nutt. Indian plantain. Rare; (D6).

Calamagrostis canadensis Michx. Bluejoint grass. Common; (E17).

Campanula aparinoides Pursh. Marsh-bellflower. Rare; (D5).

C. rotundifolia L. Harebell. Frequent; (E5, E17).

Cardamine bulbosa (Schreb.) BSP. Spring cress. Infrequent; (D5).

Ceanothus americanus L. New Jersey tea. Infrequent; (E12, E17).

Celastrus scandens L. Bittersweet. Rare; (C4) oak savanna species.

Cenchrus longispinus (Hack.) Fern. Sand bur. Frequent; (D23).

Cicuta maculata L. Spotted cowbane. Frequent; (D5).

Cirsium discolor Muhl. Old-field thistle. Rare; (C1).

C. muticum Michx. Swamp thistle. Infrequent; (D5).

Comandra unbellata (L.) Nutt. Bastard toadflax. Infrequent; (D5)

Convolvulus sepium L. Wild morning glory. Infrequent; (D1).

Conyza canadensis (L.) Cronq. Horseweed. Common; (D23).

Coreopsis palmata Nutt. Palm-leaved coreopsis. Common; (D5, D25).

Cornus racemosa Lam. Gray dogwood, prairie dogwood. Infrequent; (B6).

C. stolonifera Michx. Red osier dogwood. Common, early forest successional.

Corylus americana Walt. Hazelnut. Frequent; (D21). Oak savanna species.

Crataegus spp. L. Hawthorn. Common; (C1).

Danthonia spicata (L.) Beauv. Poverty grass. Infrequent; (E17).

Desmodium canadense (L.) DC. Showy tick-trefoil. Frequent; (E13, E17).

D. illinoense Gray. Illinois tick-trefoil. Frequent; (E13).

Dodecatheon meadia L. Shooting star. Common; (D23).

Draba reptans (Lam.) Fern. Whitlow grass. Rare; (D21, E8).

Elymus canadensis L. Canada wild rye. Frequent; (D21).

Epilobium augustifolium L. Fire weed. Infrequent; (D15).

E. coloratum Biehler. Willow herb. Infrequent; (D8).

Equisetum arvense L. Common horsetail. Frequent; (D15).

Eragrostis spectabilis (Pursh) Steud. Purple love-grass. Infrequent; (D23, E2).

Erigeron pulchellus Michx. Robin's plantain. Infrequent; (D19, E17).

E. strigosus Muhl. Daily fleabane. Frequent; (E17).

Eryngium yuccifolium Michx. Rattlesnake master. Rare; (D5, D8).

Eupatorium altissimum L. Tall boneset. Rare; (D9).

E. maculatum L. Joe-pye weed. Frequent; (E17)

E. perfoliatum L. Boneset. Frequent; (D5)

Euphorbia corollata L. Flowering spurge. Common; (D23).

Fragaria virginiana Duchesne. Wild strawberry. Common; (E17).

Galium boreale L. Northern bedstraw. Infrequent; (D5, D20).

Gentiana andrewsii Griseb. Bottle gentian. Infrequent; (D5).

G. procera Holm. Lesser fringed gentian. Infrequent; (C6, E17).

G. puberula Michx. Downy gentian. Rare; (D23).

G. quinquefolia L. Stiff gentian. Rare; (E9); oak savanna species.

Geranium maculatum L. Wild geranium. Common; (D5, D8); oak savanna species.

Gerardia purpurea L. Purple false foxglove. Rare; (D11).

G. tenuifolia Vahl. Gerardia. Rare; (E17).

Geum aleppicum Jacq. Yellow avens. Frequent; (B2, D5).

G. triflorum Pursh. Prairie smoke. Frequent; (D5, D23, E17).

Glyceria striata (Lam.) Hitchc. Fowl manna grass. Infrequent; (D5)

Gnaphalium uliginosum L. Sweet everlasting. Frequent; (E9, E17).

Grindelia squarrosa (Pursh) Duanl. Tarweed, gumweed. Infrequent; (B7, D17, E7).

Hedeoma hispida Pursh. Grassleaf pennyroyal. Infrequent; (E17).

Helenium autumnale L. Sneezeweed. Infrequent; (D5)

Helianthus annuus L. Annual sunflower. Infrequent; (C2), adventive from west

H. giganteus L. Tall sunflower. Common; (D8).

H. grosseserratus Martens. Sawtooth sunflower. Common; (D8).

H. laetiflorus Pers. Showy sunflower. Infrequent; (D23, C3).

H. maximiliani Schrader. Maximilian sunflower. Rare; (D8); probably adventive.

H. occidentalis Riddell. Naked sunflower. Rare; (D23).

H. strumosus L. Rough sunflower. Common.

Heliopsis helianthoides (L.) Sweet. Early sunflower. Infrequent; (C2).

Heuchera richardsonii R. Br. Alum root. Frequent; (D5, D13).

Hieracium longipilum Torr. Long-haired hawkweed. Infrequent; (D15, E17).

Hierochloë ordorata (L.) Beauv. Sweetgrass. Rare; (D8).

Houstonia caerulea L. Bluets. Frequent; (E17).

Hypericum kalmianum L. Shrubby St. John's-wort. Frequent; (D5).

Hypoxis hirsuta (L.) Cov. Yellow star grass. Frequent; (D19).

Iris virginica L. Wild blue flag. Infrequent; (D5, D8).

Koeleria cristata (L.) Pers. Junegrass. Infrequent; (E17).

Krigia biflora (Walt.) Blake. Two-flowered cynthia. Infrequent; (D5)

Kuhnia eupatorioides L. False boneset. Frequent; (D23, E14).

Lactuca canadensis L. Wild lettuce. Rare; (D23)

L. floridana (L.) Gaertn. Blue lettuce. Infrequent; (D5).

Lathyrus palustris L. Wild pea. Infrequent; (D5).

L. venosus Muhl. Vetchling. Frequent; (D5).

Lespedeza capitata Michx. Roundheaded bush-clover. Common; (E9).

Liatris aspera Michx. Button-snakeroot. Frequent; (D23).

L. cylindracea Michx. Dwarf blazing star. Infrequent; (D23).

L. ligulistylis (A. Nels.) K. Schum. Infrequent; (B1, D25).

L. pycnostachya Michx. Dense gaygeather. Infrequent; (D5).

L. spicata (L.) Willd. Gaygeather. Rare; (D5).

Lilium superbum L. Turk's cap lily. Infrequent; (B3, D11).
L. philadelphicum L. Wood lily. Rare; (D5).
Lithospermum canescens Michx. Orange puccoon. Frequent; (D23).
L. incisum Lehm. Yellow puccoon. Rare; (D23).
Lobelia kalmii L. Kalm's lobelia. Infrequent; (D5).
L. siphilitica L. Great lobelia. Rare; (E17).
L. spicata Lam. Pale spiked lobelia. Common; (E9).
Lupinus perennis L. Wild lupine. Infrequent; (D16).
Lycopus americanus Muhl. Cut-leaved water horehound. Infrequent; (D5).
Lysimachia quadriflora Sims. Prairie loosestrife. Infrequent; (D5).
Monarda fistulosa L. Wild bergamot. Common.
Muhlenbergia racemosa Michx. Green muhly grass. Infrequent; (E17).
M. mexicana (L.) Trin. Muhly grass. Infrequent; (D8, E17).
Oenothera biennis L. Evening primrose. Frequent; (B1).
O. serrulata Nutt. Toothed evening-primrose. Rare; (C2); probably adventive from at least as far west as western Wisconsin.
Oxalis stricta L. Tall wood sorrel. Frequent; (D23).
Oxybaphus nyctagineus (Michx.) Sweet. Wild four o'clock. Infrequent; (B4, C2); adventive.
Oxypolis rigidior (L.) Raf. Cowbane. Infrequent; (D5).
Panicum capillare L. Witchgrass. Frequent; (D15).
P. dichotomum L. Rare; (D5).
P. implicatum Scribn. Hairy panic grass. Infrequent; (D22, E17).
P. leibergii (Vasey) Scribn. Prairie panic grass. Infrequent; (D23).
P. oliganthes Schultes var. schribnerianum (Nash) Fern. Schribner's panic grass. Infrequent; (D12, E10).
P. praecocium Hitchc. & Chase. Early panic grass. Infrequent; (E17).
P. virgatum L. Switchgrass. Infrequent; (D12).
P. xanthophysum Gray. Yellow panic grass. Rare; (E10).
Parnassia glauca Raf. Grass of parnassus. Rare; (D5).
Pedicularis canadensis L. Lousewort. Rare; (D23).
P. lanceolata Michx. Wood betony. Rare; (E17).
Penstemon digitalis Nutt. Smooth penstemon. Rare; (E14).
Petalostemum candidum (Willd.) Michx. White prairie clover. Infrequent; (E16, D23).
P. purpureum (Vent.) Rydb. Purple prairie clover. Frequent; (D23).
Phlox pilosa L. Downy phlox. Infrequent; (D23).
Physalis heterophylla Nees. Clammy ground cherry. Infrequent; (E11).
P. virginiana Mill. Ground cherry. Frequent; (D17).
Plantago patagonica Jacq. Sand plantain. Rare; (E10).
Polygala sanguinea L. Field milkwort. Infrequent; (E17).
P. senega L. Seneca snakeroot. Infrequent; (D10).
Polygonatum biflorum (Walt.) Ell. Solomon's seal. Common; (D23).
Potentilla arguta Pursh. Tall cinquefoil. Frequent; (D5).
P. furticosa L. Shrubby cinquefoil. Frequent; (E17).
P. norvegica L. Rough cinquefoil. Frequent; (E10).
P. simplex Michx. Common cinquefoil. Frequent; (E14).
Prenanthes racemosa Michx. Rattlesnake root. Rare; (D5).
Prunella vulgaris L. Heal-all. Infrequent; (A1, E1).
Prunus pumila L. Sand cherry. Infrequent; (D5, D23).
Pychnanthemum virginianum (L.) Durand & Jackson. Prairie hyssop. Infrequent; (D5).
Quercus macrocarpa Michx. Bur oak. Common; oak savanna species.
Ranunculus fascicularis Muhl. Early buttercup. Common; (E17).
R. rhomboideus Goldie. Prairie buttercup. Infrequent; (D24).
Ratibida pinnata (Vent.) Barnh. Gray-headed coneflower. Common.
Rhus glabra L. Smooth sumac. Common; early forest successional.
Rosa carolina L. Wild rose. Common.
Rubus allegheniensis Porter. Blackberry. Infrequent; (E17).
R. occidentalis L. Black raspberry. Common; (E17).
R. strigosus Michx. Red raspberry. Infrequent; (D14).
Rudbeckia hirta L. Balck-eyed Susan. Common.
R. triloba L. Thin-leaved coneflower. Infrequent; (E17).
Salix humilis Marsh. Prairie willow. Infrequent; (D23).
Sanicula gregaria Bickn. Black snakeroot. Rare; (D5).
Saxifraga pennsylvanica L. Swamp saxifrage. Infrequent; (D5).
Scrophularia lanceolata Pursh. Figwort. Infrequent; (D12).
Scutellaria glaericulata L. Marsh skullcap. Rare; (D2).
S. leonardi Epl. Skullcap. Rare; (E10).
Senecio pauperculus Michx. Golden ragwort. Infrequent; (D5).
S. plattensis Nutt. Hairy golden ragwort. Infrequent; (E11).
Silphium integrifolium Michx. Rosinweed. Frequent; (D4).
S. laciniatum L. Compass plant. Infrequent; (D5).
S. terebinthinaceum Jacq. Prairie dock. Common.
Sisyrinchium albidum Raf. Blue-eyed grass. Frequent; (D7).
Smilacina racemosa (L.) Desf. False spikenard. Infrequent; (E5); oak savanna species.
S. stellata (L.) Desf. Starry smilacina. Infrequent; (D14)
Smilax herbacea L. Carrion flower. Infrequent; (D13); oak savanna species.
Solanum carolinense L. Horsenettle. Infrequent; (D17); adventive.
S. rostratum Dunal. Buffalo-bur. Infrequent; (D13): adventive from Great Plains.
Solidago rugosa Mill. (S. altissima L.). Tall goldenrod. Common; (D5)
S. canadensis L. Canada goldenrod. Infrequent; (D5).
S. gigantea Ait. Late goldenrod. Frequent; (D5)
S. graminifolia (L.) Salisb. Lance-leaved goldenrod. Infrequent; (D6)
S. juncea Ait. Early goldenrod. Infrequent; (E14).
S. nemoralis Ait. Grey goldenrod. Frequent; (E17).
S. ohioensis Riddell. Ohio goldenrod. Infrequent; (D6).
S. riddellii Frank. Fen goldenrod. Rare; (D5).
S. rigida L. Rigid goldenrod. Frequent; (B1).
S. speciosa Nutt. Showy goldenrod. Infrequent; (D5, D13).
Sorghastrum nutans (L.) Nash. Indian grass. Common; (E4).
Spartina pectinata Link. Cordgrass. Common; (D8).
Spiraea alba Duroi. Meadow sweet. Frequent; (E6).
Spiranthes cernua (L.) Rich. Ladies' tresses orchid. Rare; (D5).
Sporobolus asper (Michx.) Kunth. Rough dropseed. Infrequent; (C5, E3).
S. cryptandrus (Torr.) Gray var. fusicolor (Hook.) Fassett & Jones. Sand dropseed. Rare; (exact location unknown, possibly D14, D15, or D23).
S. heterolepis Gray. Prairie dropseed. Frequent; (D5, D23, E17).

Stachys palustris L. Hedge-nettle. Rare; (E17).
S. tenuifolia Willd. Rough hedge-mint. Infrequent; (D23, E6).
Stipa spartea Trin. Needlegrass. Frequent; (D23, E5).
Taenidia integerrima (L.) Drude. Yellow pimpernel. Infrequent; (D8, D11, D12).
Thalictrum dasycarpum Fisch. & Ave'-Lall. Purple meadow rue. Frequent; (D5, D8).
Thaspium trifoliatum (L.) Gray. Meadow parsnips. Infrequent; (D12).
Tradescantia ohioensis Raf. Spiderwort. Common.
Valeriana edulis Nutt. Edible valerian. Infrequent; (D5).
Verbena hastata L. Marsh vervain. Common.
V. stricta Vent. Hoary vervain. Common.
Veronica serpyllifolia L. Thyme-leaved speedwell. Rare; (E17); oak savanna species.
Veronicastrum virginicum (L.) Farw. Culver's root. Frequent; (D5, D8).
Vicia americana Muhl. American vetch. Infrequent; (D5)
V. caroliniana Walt. Vetch. Infrequent; (D5)
Viola palmata. Palm-leaved violet. Rare; (E17); oak savanna species.
V. papilionacea Pursh. Meadow violet. Frequent; (E8).
V. pedata L. Bird-foot violet. Frequent; (E8, E17).
V. pedatifida G. Don. Prairie violet. Infrequent; (D23, E17).
V. sagittata Ait. Arrow-leaved violet. Rare; (E17).
Vitis vulpina L. Wild grape. Common.
Zizia aptera (Gray) Fern. Golden alexanders. Rare; (C1)
Z. aurea (L.) Koch. Golden alexanders. Infrequent; (D12).
Zygadenus elegans Pursh. Death camas. Infrequent; (D3, E11).

DISCUSSION

Of the 243 species listed in the catalogue, 6 appear to be adventive from more western areas of the United States. There are 2 other species, Cornus stolonifera and Rhus glabra, that are probably not prairie species as much as they are early prairie-forest successionals. There are 9 species listed that are more characteristic of oak openings than true prairie.

In the catalogue, 49 entries are listed as "rare," 1 entry as "rare or infrequent," 99 as "infrequent," 53 as "frequent," and 41 as "common." The remnant with the most rare species, 12, is the Scuppernong Wet Meadow Scientific Area (D5). The Windworks Prairie (E17) has 8 rare ones. The Doman Remnant (D23) has 5, and the Stonegate complex (E9, E10, and E11) also has 5 species listed are "rare" in the catalogue of species. The remaining 24 sightings of rare plant species come from an additional 17 collection sites. 6 collection sites are included in this inventory simply because they contain 1 rare species.

No species entered in the catalogue is a first sighting for Wisconsin. However, Panicum dichotomum, which grows along the north side of the dirt road leading through the Scuppernong Wet Meadow, has its second state appearance recorded in this catalogue.

A number of prairie remnants have survived the past 140 years, but present demographic trends jeopardize even these. It is ironic that many valuable remnants are disappearing each year for the sake of some "back-to-nature" subdivisions. Others are being obliterated by farmers who, feeling a pressure to produce more food, plow up marginal crop land. Still other remnants are lost to more frequent roadside mowings. Remnants that are surviving are doing so only in various states of degradation. Many have not been burned for 30 years or more; their vigor has been lost. Early- and mid-successional prairie species have disappeared, leaving Eurasian weeds to recolonize the gaps left by animal diggings, disease, or heavy accumulations of litter. Other remnants are degraded because cattle have grazed them. These lack some of the more fragile mid- and late-season species. A sixth bane to prairies is tree plantations. Lastly all remnants suffer by being small and isolated. In order for all the plant and animal species of a prairie to survive over a long period of time much land is needed. Terborgh (1974) suggests 1000 km^2 is needed to sustain a complete permanent prairie. Presently on the small, disjointed remnants, plant populations stand little chance of being recolonized once they have been eliminated by disease, inbreeding, overgrazing, competition or other catastrophy.

The species composition of the different remnants is quite varied, and may in some way reflect the great variety contained in the prairies of earlier times. It may also be that their different compositions are a reflection of isolation followed by disturbance.

ACKNOWLEDGMENTS

For their much appreciated encouragement and advice, I thank Clifford E. Germain and William Tans, both of the Wisconsin Department of Natural Resources; Jerome Schwarzmeier of the Waukesha County Parks and Planning Commission; and Richard Barloga.

LITERATURE CITED

Fassett, N. C. 1951. Grasses of Wisconsin. Univ. Wis. Press, Madison. 173 p.

Gleason, H. A., and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and adjacent Canada. D. Van Nostrand Co., N.Y. 810 p.

Schwarzmeier, J., and M. Johnson. 1975. Presettlement vegetation of Waukesha County, 1936. Unpublished map. Wis. Dept. Nat. Resources.

Steingraeber, J. A., and C. A. Reynolds. 1971. Soil survey of Waukesha and Milwaukee Counties, Wisconsin. U.S. Dept. Agr. Soil Cons. Ser. 332 p.

Terborgh, J. 1974. Preservation of natural diversity: The problem of extinction-prone species. BioScience 24:715-722.

EFFECT OF PRAIRIE AND FOREST VEGETATION ON PHOSPHORUS STATUS OF IOWA SOIL PROFILES

F. F. Riecken
Department of Agronomy
Iowa State University
Ames, Iowa 50011

and

B. R. Tembhare
Department of Soil Science
J. N. Agril University
Adhartal, Jabalpur, M. P., India

ABSTRACT

In 1854, prairie covered about 82 percent of Iowa. Influence of prairie versus forest on phosphorus status of Iowa soils has long been of interest. In this study, Bray I Available Phosphorus (AP) was determined in prairie, transition (forest encroachment on prairie) and forest soil profiles for well, somewhat poor, and poor natural drainage soil sequences. Prairie soils in each biosequence were lower in AP than were forest soils, regardless of drainage sequence. Transition soils were similar to forest soils in AP.

INTRODUCTION

Prairie was the native vegetation for about 82 percent of Iowa land (Davidson 1961). The distribution of the original prairie and forest is shown in Fig. 1, an often reproduced map (Oschwald et al. 1965).

In the classification and mapping of the soils of Iowa it has long been recognized that vegetation was an important soil forming factor. In early soil surveys, the soils were subdivided into prairie soils and forest soils (Marean and Jones 1904). The prairie Marshall soils typically had a 45 cm thick black surface soil, and the forest Miami soil had only a few centimeters of organic-mineral soil. Although the main vegetative divisions were prairie and forest, later, a third division was recognized. It was first called a light colored phase of a prairie soil, but has become to be known as a "transition soil", presumably forest encroachment on prairie. In the early years of soil classification, identification of kind of soil with native vegetation in Iowa outranked parent material and natural drainage. These latter factors, however, soon were recognized as important contributors to kind of soil (Oschwald et al. 1965).

A model for viewing potential kinds of soils in Iowa is outlined in Table 1. Each parent material situation may have three natural drainage situations. If there are three kinds of native vegetation, there result nine kinds of soils, or soil series. In the model, parent material is used in a quite restricted sense. The soils of one material of one drainage class but differing in original vegetation are referred to as a biosequence. Thus, in Table 1, the Clarion biosequence consists of the Clarion-Lester-Hayden series. In the loess material example, the Seymour biosequence consists of the Seymour-Kniffen-Rathbun series. In this sequence, and in the Edina and Grundy sequences, the well drained member is not present in the soilscape.

Association of kind of vegetation and phosphorus

Table 1. General Model for soil series in Iowa.

Parent Material	Natural Drainage[(a)] Class	Original Vegetation[(a)]: Prairie (P)	Transition (F/P) Series	Forest (F)
Cary loam glacial till	Well	Clarion	Lester	Hayden
	Somewhat poor	Nicollet	LeSeuer	Luther
	Poor	Webster	Dundas	Ames
Wisconsin loess (60-90 inches thick) over till paleosol	Well	a	a	a
	Somewhat poor	Seymour	Kniffin	Rathbun
	Poor	Edina	Appanoose	a
Another parent material	Well	X^1	X^2	X^3
	Somewhat poor	Y^1	Y^2	Y^3
	Poor	Z^1	Z^2	Z^3

(a) Some drainage and vegetation classes may be absent.

Table 2. Bray I available phosphorus (AP) and pH in B horizon of maximum AP value.

Soil Biosequence	Natural Drainage Class	Maximum AP Value in B Horizon					
		Prairie (P)		F/P[(b)]		Forest (F)	
		AP ppm	pH	AP ppm	pH	AP ppm	pH
Cary loam till parent material							
1. Clarion	Well	6	6.0	18	5.3	28	4.9
2. Nicollet	S.[(a)] Poor	9	6.2	12	5.7	17	5.0
3. Webster	Poor	7	6.7	25	6.6	17	4.8
Average		7		18		21	
Wisconsin loess parent material							
4. Otley	Well	18	5.2	44	5.4	66	5.3
5. Mahaska	S. Poor	27	5.5	52	5.1	50	6.1
6. Taintor	Poor	8	7.3	27	5.2	74	4.9
7. Grundy	S. Poor	12	5.2	42	5.4	53	4.6
8. Haig	Poor	12	6.0	44	5.3	47	4.6
9. Seymour	S. Poor	16	5.6	30	6.3	57	4.3
10. Edina	Poor	12	6.0	49	6.0		
11. Nira	S. Poor	5	5.8	39	5.7		
12. Sharpsburg	Well	18	5.8	63	5.5		
Average		14		43		56	

(a) S = somewhat

(b) F/P = forest/prairie

in soil profiles from Iowa was recognized by Pearson et al. (1940). Acid-soluble (0.002N H_2SO_4) P tended to be greater in forest-derived soils than in prairie soils of similar parent material origin. This form of P was considered available to sweet clover but less so to corn. Fenton et al. (1967) reported for Iowa soil profiles that total P tends to be greatest in forest, intermediate in prairie, and least in transition soils of common parent material. Unpublished results (private communication Lloyd C. Dumenil, Department of Agronomy, Iowa State University, Ames) of available phosphorus (AP) by the Bray I soil test indicate that a greater amount of AP is present in B horizons of forest soils than in prairie soils of common parent material origin. Information on the AP of the soil profiles of Iowa soil types is used in making fertilizer recommendations (Voss, 1973). Lesser amounts of phosphorus fertilizer are recommended if the subsoil has appreciable amounts of AP. Because the Bray I test seems to differentiate prairie soils from forest soils better than the acid-soluble test, we selected the Bray I test. The Bray I extractant is a solution of 0.025 N HCL and 0.035 N NH_4F, using a 1:10 soil:extractant ratio (Tembhare 1973).

SOIL STUDIES

Soil profiles collected for other studies were used where possible. The previous identification by series has been continued, including the vegetative origin. Further details of the soils reported in this study are given elsewhere as are the details of the Bray I AP procedure (Tembhare 1973). The Bray I AP was determined on 33 soil profiles. Results are reported as parts per million.

Biosequences from Cary Loam Till

The AP of the profiles of the Clarion biosequence are plotted in Fig. 2. The striking feature of these data is the AP values in the 25- to 75-cm zone, or the B horizon. The Hayden, a forest soil (F), has clearly more AP in the B horizon than does Clarion, a prairie soil (P). Lester, a transition soil, forest-prairie (F/P) is intermediate in B horizon AP. The Clarion biosequence is naturally well drained.

The AP of the poorly drained Webster biosequence profiles are plotted in Figure 3. The AP values are similar in the upper layers, but are quite different in the 30- to 60-cm B horizon. The increasing order of AP values is Webster (Prairie), Ames (Forest), Dundas (Forest/Prairie), or P, F, F/P.

The AP values of the B horizons of the Nicollet biosequence are summarized in Table 2. The AP value reported is the highest value of this horizon. For example, the AP of Dundas in Table 2 is 25 ppm AP and also is the highest value in the B horizon at about the 75-cm depth in Fig. 3. In the Nicollet biosequence, the AP increases from P to F/P to F. The three prairie soils average 7 ppm AP in the B, the F/P soils 18, and the forest soils 21 ppm (Table 2).

Biosequences from Wisconsin Loess

The AP of the profiles of the Seymour sequence are plotted in Fig. 4. In the B horizon zone from about 50 to 100 cm, the increasing order of AP is Seymour to Kniffin to Rathbun, or P, F/P, F.

The highest AP value in the B horizon of each soil profile analyzed is given in Table 2 for the various biosequences from loess. For example, the highest AP in the Rathbun is 57 ppm at about 75 cm, and this value is listed in Table 2 for the F soil of the Seymour biosequence. The Seymour biosequence soils have clay textured B horizons and are strongly developed (Oschwald et al. 1965). They have formed in 150- to 225-cm thick Wisconsin loess, which overlies paleosols from Kansan glacial till.

For each of the other biosequences of Table 2, the prairie member has lower AP than the F/P or F member. For example in the Otley biosequence, the P soil has 18 ppm AP in the B horizon, the F/P has 44 and the F soil has 66 ppm.

The Otley biosequence soils have about 40 percent clay in the B and are of medium development. The Otley sequence members have somewhat more AP than the respective Seymour members. The Grundy sequence is intermediate in development to Otley and Seymour. The Grundy F/P and F members are intermediate in AP to Otley F/P and F members, but the differences are not great. Thus, degree of B horizon clay development does not seem to affect maximum AP B horizon values to any great extent. The striking differences are between the prairie member of the various sequences as compared with the F/P or F members.

The strong difference between the P and the F and F/P members does not seem to be affected by natural drainage class. The F and F/P members of the Taintor and Mahaska biosequences are clearly higher in B horizon AP than are the respective P members. The same comparison can be made of the Grundy and Haig biosequences. The Haig sequence is more poorly drained than the Grundy sequence, yet the F/P and F members have comparable, but high, AP values as compared with the P members. A similar comparison of the poorly drained Edina and the somewhat poorly drained Seymour sequences indicates that the respective F/P members have higher AP values than do the P members.

Effect of Parent Material

The average AP is given in Table 2 of the various P, F/P, and F sequence members from loess and Cary loam till. The loess soils, whether P, F/P, or F in origin, average about twice as high in AP in the B horizon than do Cary loam till soils. This may be partly the result of higher initial total phosphorus in loess soils in Iowa. Pearson et al. (1940) reported that glacial till parent materials averaged about 300 ppm total P, and loess parent materials about 700 ppm.

Eroded Prairie Soils

About 26 percent of Iowa soils have slope gradients of 5 to 14% (Arnold et al. 1960). Some counties have 50% of their soils in these slope gradients. Most of these soils are, or have been, cultivated and erosion has removed about half of the original surface layer. The organic carbon content of a moderately sloping (C, or 5-9% slope) moderately eroded (370C2), and uneroded (370C) prairie Sharpsburg soil are given in Fig. 5. These loess derived soils are from Adair County, which had about 92% prairie cover in the 1830-50 period on the basis of data by Davidson (1961). The uneroded prairie Sharpsburg (370C) has a 15-inch (38 cm) layer of surface soil with more than 0.58% organic carbon. Once formally called a Prairie soil, then Brunizem, it now is called a Mollisol (Soil Survey Staff, 1972). Because it is in a climate of Iowa rainfall and annual temperature it is called a Udoll, or moist or Udic Mollisol. To qualify as a Udoll, a soil must have at least 25 cm of dark surface soil, a mollic horizon with more than 0.58% organic carbon, and a defined base saturation and Munsell color (Soil Survey Staff, 1973). The depth and percentage carbon limits are indicated by hachures in Fig. 5.

The eroded Sharpsburg soil, 370C2 of Fig. 5, has only 12 to 15 cm of mollic horizon; therefore it does not qualify as a Udoll by the mollic rule. The current trend is to correlate such eroded prairie soils as taxadjuncts to a Udoll series. In this instance, soil 370C2 would be a taxadjunct to the Sharpsburg series. These kinds of eroded prairie soils are currently considered to be outside the soil taxonomic system. In some sloping counties of Iowa where prairie cover was dominant, as much as one-fourth to one-third of the soils are of this kind.

Appropriate taxonomy of the eroded prairie soils needs attention. One alternative is to place some of them with the Alfisols. As shown in Fig. 5, the 370C2 soil has organic carbon content like the Ladoga (76C2) series, also a loess derived soil. The Ladoga is a transition, F/P, soil. As shown in Fig. 6, however, Ladoga has much more AP in the lower profile than does the eroded Sharpsburg soil. As shown in Table 2 for the Nira sequence, also a loess derived sequence, the P member also is an eroded prairie soil. It has 5 ppm AP in the B horizon. The F/P member has 39 ppm AP. This eroded prairie soil also would be considered a taxadjunct to the Nira series and outside the soil taxonomic system.

Transition Soils

Although the transition (F/P) soils as a group and in individual biosequences have more AP than the prairie soil member, several of the F/P soils studied are strong candidates for Udolls or Aquolls (wet Mollisols) because of the mollic rule. The F/P soil of the Nicollet biosequence has a 37 cm thick surface layer with more than 1/3% organic carbon (Tembhare 1973). It would seem to qualify as a Udoll as regards the mollic rule, although its AP values are indicative of forest influence. The F/P soil of the Seymour sequence has a 35 cm thick dark surface layer, with more than 1.52% organic carbon. It, too, would seem to qualify as a Udoll, although its AP value is clearly indicative of forest influence (Fig. 4).

The F/P soil profile of the Nicollet sequence at the time of sampling was identified as the LeSueur series, a forest-prairie intergrade (Tembhare, 1973). Currently, the LeSueur series is classified as an Argiudoll (Soil Survey Staff, 1972), but is recognized as having formed under mixed deciduous forest and prairie. The F/P soil profile of the Seymour sequence was identified as the Kniffin series at the time of sampling (Tembhare 1973). This series is classified as a Udollic Ochraqualf (Soil Survey Staff, 1972), but as noted earlier it is borderline to, and

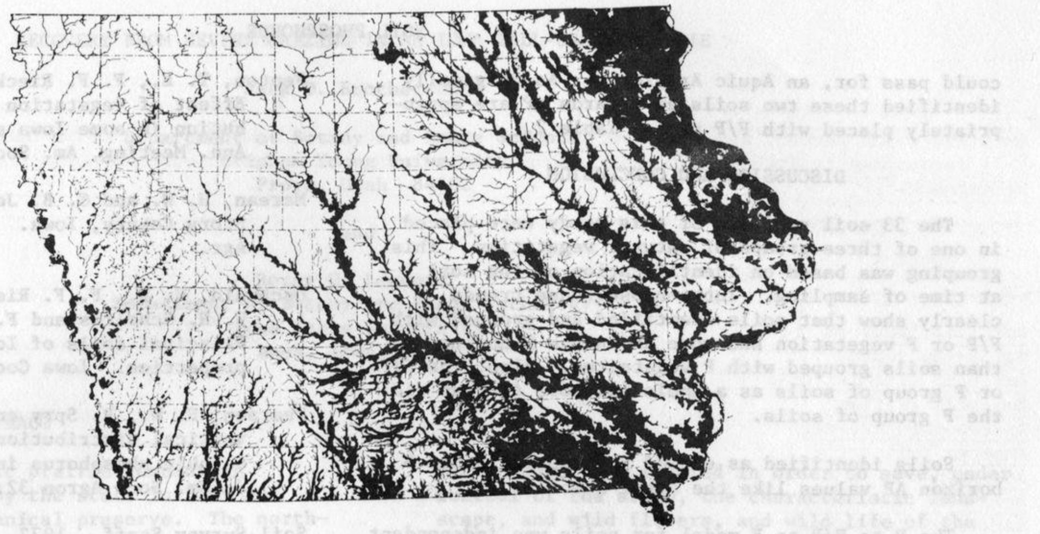


Fig. 1. Vegetation Cover in Iowa in 1832-59: Forest shaded, prairie clear.

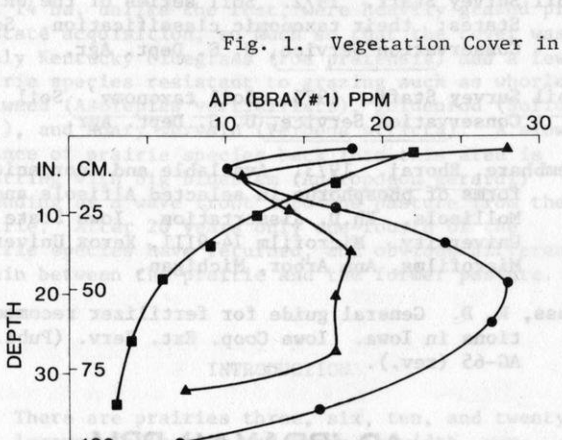


Fig. 2. Clarion biosequence: Distribution of Bray I available phosphorus (AP) in well-drained prairie (P), forest (F), and forest-prairie (F/P) soil profiles in Cary loam glacial till.

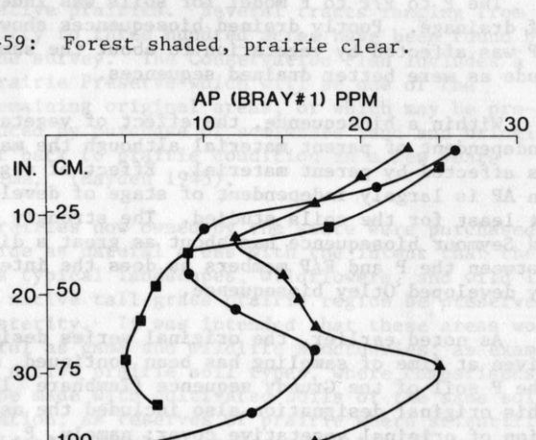


Fig. 3. Webster biosequence: Distribution of Bray I available phosphorus (AP) in poorly drained prairie (P), forest (F), and forest/prairie (F/P) soil profiles.

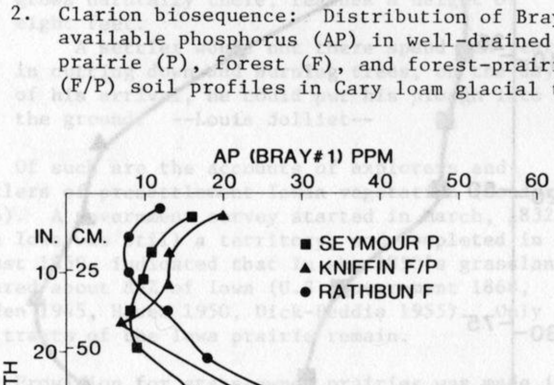


Fig. 4. Seymour biosequence: Distribution of Bray I available phosphorus (AP) in prairie (P), forest (F), and forest/prairie (F/P) soil profiles.

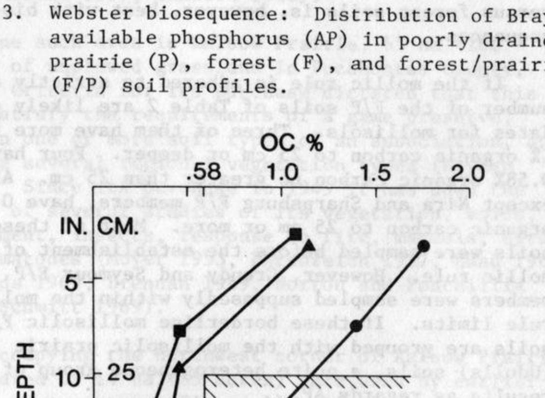


Fig. 5. Organic carbon (OC) in profiles of Ladoga (75C2), eroded Sharpsburg (370C2), and uneroded Sharpsburg (370C) soils.

could pass for, an Aquic Arguidoll. As originally identified these two soils as regards AP are appropriately placed with F/P soils, Table 2.

DISCUSSION AND CONCLUSION

The 33 soil profiles of this study were placed in one of three groups of natural vegetation. This grouping was based on identification of the soil at time of sampling. Intra-biosequence trends clearly show that soils identified and grouped with F/P or F vegetation had more AP in the B horizon than soils grouped with P vegetaiton. Also, the F/P or F group of soils as a whole had more AP than did the P group of soils.

Soils identified as eroded prairie soils had B horizon AP values like the other P soils.

The P to F/P to F model for soils was independent of drainage. Poorly drained biosequences showed that AP was affected by vegetation to about the same magnitude as were better drained sequences.

Within a biosequence, the effect of vegetation is independent of parent material although the magnitude is affected by parent material. Effect of vegetation on AP is largely independent of stage of development, at least for the soils studied. The strongly developed Seymour biosequence has about as great a difference between the P and F/P members as does the intermediately developed Otley biosequence.

As noted earlier, the original series designation given at time of sampling has been continued, except the P soil of the Grundy sequence (Tembhare 1973). This original designation also included the assumption of original vegetative cover; namely, P, F/P or F (Table 2). In none of the biosequences does the P soil exceed the F/P or F soil in AP. To that extent, there is good correspondence between original vegetative designation and AP. A quite homogeneous grouping results if soils are grouped by using the model in Table 2. Use of AP to differentiate prairie versus forest soils is, however, best with biosequences.

If the mollic rule is adhered to strictly a number of the F/P soils of Table 2 are likely candidates for mollisols. Three of them have more than 1% organic carbon to 25 cm or deeper. Four have 0.58% organic carbon to greater than 25 cm. All, except Nira and Sharpsburg F/P members, have 0.58% organic carbon to 25 cm or more. Most of these F/P soils were sampled before the establishment of the mollic rule. However, Grundy and Seymour F/P members were sampled supposedly within the mollic rule limits. If these borderline mollisolic F/P soils are grouped with the mollisolic prairie (Udolls) soils, a quite heterogeneous group of soils results as regards AP.

LITERATURE CITED

Arnold, R. W., L. E. Tyler and F. F. Riecken. 1960. Estimate of slope classes by counties in Iowa. Proc. Iowa Acad. Sci. 67:260-267.

Davidson, R. R. 1961. Comparisons of the Iowa Forest Resource in 1832 and 1954. Iowa State Sci. 36:133-136.

Fenton, T. E., F. F. Riecken and J. E. Seaholm. 1967. Effect of vegetation on total phosphorus distribution in some Iowa soils. Agron. Abstr. 59th Ann. Meeting, Am. Soc. Agron. p. 117.

Marean, H. W. and G. B. Jones. 1904. Soil Survey of Story County, Iowa. Bureau of Soils, U. S. Dept. Agr.

Oschwald, W. R., F. F. Riecken, R. I. Dideriksen, W. H. Scholtes and F. W. Schaller. 1965. Principal soils of Iowa: their formation and properties. Iowa Coop. Ext. Serv. Spec. Rep. 42.

Pearson, R. W., R. Spry and W. H. Pierre. 1940. The vertical distribution of total and dilute acid-soluble phosphorus in twelve Iowa soil profiles. J. Am. Soc. Agron 32:683-696.

Soil Survey Staff. 1972. Soil series of the United States: their taxonomic classification. Soil Conservation Service, U. S. Dept. Agr.

Soil Survey Staff. 1973. Soil taxonomy. Soil Conservation Service, U. S. Dept. Agr.

Tembhare, Bhoraj. 1973. Available and inorganic forms of phosphorus in selected Alfisols and Mollisols. Ph.D. dissertation. Iowa State University. Microfilm 74-9111, Xerox University Microfilms, Ann Arbor, Michigan.

Voss, R. D. General guide for fertilizer recommendations in Iowa. Iowa Coop. Ext. Serv. (Publ.) AG-65 (rev.).

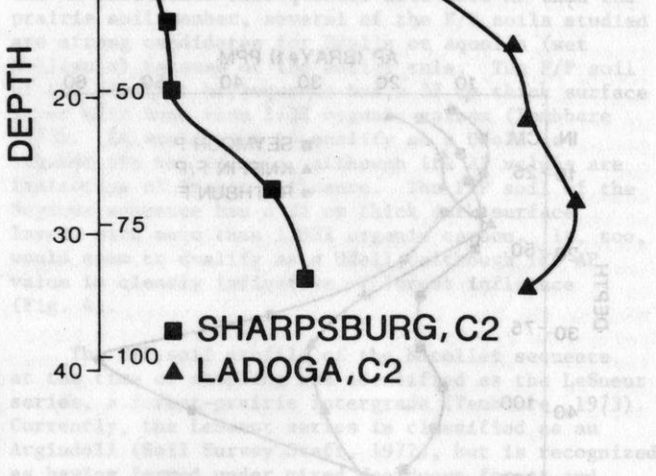


Fig. 6. Bray I available phosphorus (AP) in Ladoga (forest/prairie) and sloping eroded (C2) Sharpsburg prairie soils.

RECOVERY FROM SEVERE GRAZING IN AN IOWA TALL-GRASS PRAIRIE

Jack D. Brotherson

Department of Botany and Range Science
Brigham Young University
Provo, Utah 84602

and

Roger Q. Landers
Department of Botany and Plant Pathology
Iowa State University
Ames, Iowa 50011

ABSTRACT

Kalsow Prairie, a mesic prairie remnant in central Iowa was acquired by the state in 1949 and later established as a botanical preserve. The northwest 14 ha, unlike the rest, were heavily grazed prior to state acquisition, so much so that the cover was mainly Kentucky bluegrass (Poa pratensis) and a few prairie species resistant to grazing such as whorled milkweed (Asclepias verticillata), goldenrod (Solidago spp.), and hoary vervain (Verbena stricta). A slow advance of prairie species back into this area is occurring with big bluestem (Andropogon gerardi) extending as a wave front into the pasture from the prairie. After 20 years only one-fourth of the prairie species have returned, and obvious differences remain between the prairie and the former pasture.

INTRODUCTION

> There are prairies three, six, ten, and twenty leagues in length, and three in width, surrounded by forests of the same extent; beyond these, the prairies begin again, so that there is as much of one sort of land as of the other. Sometimes we saw the grass very short, and, at other times five or six feet high; hemp, which grows naturally there, reaches a height of eight feet.
>
> A settler would not there spend ten years in cutting down and burning trees; on the day of his arrival, he could put his plough into the ground. --Louis Jolliet--

Of such are the accounts of explorers and settlers of presettlement Iowan vegetation (Dondore 1926). A government survey started in March, 1832, when Iowa was still a territory, and completed in August 1859, indicated that in the 1850's grassland covered about 85% of Iowa (U.S. Government 1868, Hayden 1945, Hewes 1950, Dick-Peddie 1955). Only a few tracts of the Iowa prairie remain.

Provision for state-owned prairies was made in 1933 when the Iowa State Conservation Commission prepared a report known as the Iowa Twenty-five Year Conservation Plan. In a section of this report the following proposal was recommended:

> Prairie Preserve--Recommended. Along the railroad rights-of-way, and here and there in small patches throughout the state, unbroken virgin prairie sod is still to be found. Some of these will be saved because they lie within protected areas, or simply because the ground cannot be used for farm purposes. But somewhere in Iowa a large enough original tract of prairie vegetation should be secured in order to save, under control of the state, the characteristic landscape, and wild flowers, and wild life of the native prairies. Several tracts ranging from forty to three hundred acres have been found by the survey. The Conservation Plan includes a Prairie Preserve which will be one of the remaining original areas, or which may be produced by purchase of semiwaste land and bringing it back to prairie condition in a few years' time. (Hayden 1945).

Prairies now owned by the state were purchased and set aside as natural areas with the intent that the various typical landscapes, wildflowers, and wild life of the native tall-grass prairie region be preserved for posterity. It was intended that these areas would be useful as game and wildlife sanctuaries; as examples of the native prairie soil types, where comparisons could be made with cultivated soils of the same soil association; as reserves of prairie where scientific investigations could be made on problems concerning the native vegetations, floras and faunas of the various topographic, climatic, and prairie districts throughout Iowa. Therefore, they now serve as reference points by which we may compare the influences of man on Iowa since settlement (Hayden 1946, Moyer 1953, Aikman 1959, Landers 1966).

One such area is Kalsow Prairie, 65 ha (160 acres) of unplowed grassland in Pocahontas County, Iowa. Criteria for its purchase dictated that this area satisfy the requirements of a game preserve, contain one or more soil types of an association, and include several regional vegetation types (Hayden 1946). Since its purchase in 1949 it has been the object of several studies of its vegetation, soils, management, insects, response to fire, mammals, birds and nematodes (Moyer 1953, Ehrenreich 1957, Esau 1968, Richards 1969, Brennan 1969, Norton and Ponchillia 1968, Schmitt 1969).

Occupying the northwest corner of Kalsow Prairie is an area of 14 ha (35 acres) once used by earlier owners as a pasture (Figure 1). At the acquisition of the rest of the prairie in 1949 these 14 ha were also purchased and added to the prairie. All old fences were removed, and the full 65 ha were enclosed as a unit. The intention was to encourage the native prairie plants found adjacent to the pasture's south and east boundaries to serve as a seed source and thus eventually this grazed area would be expected to return to native prairie.

This investigation was undertaken to provide information on species composition and distribution, factors affecting the distributional patterns of

TABLE 1

Occurrence and percent average cover of plant species found in the grazed area of Kalsow Prairie. The numbers 1-11 correspond to the identification numbers of the different treatments found in Table 2, an X indicating occurrence.

Species	Ave. % cover	1	2	3	4	5	6	7	8	9	10	11
Achillea lanulosa	.17						X					
Agropyron repens	.02						X	X				
Ambrosia artemisifolia	.58					X	X					
Ambrosia trifida	.01						X					
Andropogon gerardii	34.01			X			X			X		
Anemone cylindrica	.01						X	X	X	X		
Apocynum sibricum	.01						X	X			X	
Artemisia ludoviciana	.03						X	X	X	X		
Asclepias incarnata	.01						X	X			X	
Asclepias syriaca	.36						X	X				
Asclepias verticillata	.01						X	X				
Aster ericoides	.94				X		X	X				
Aster laevis	.01						X	X	X	X		
Aster novae-angliae	.03						X	X	X	X		
Aster simplex	.46						X	X	X	X	X	
Bouteloua curtipendula	.01						X	X	X	X		
Bromus inermis	.38						X	X				
Carex retrorsa	.02						X	X			X	
Carex lasiocarpa	.14						X	X			X	
Chenopodium album	.01						X	X				
Cirsium altissimum	.03						X	X				
Cirsium arvense	.74						X					
Convolvulus sepium	.03						X	X				
Desmodium canadense	.03						X	X	X	X		
Elymus canadensis	.01						X	X	X	X		
Equisetum arvense	.01						X				X	
Equisetum kansanum	.06						X	X	X	X	X	
Fragaria virginiana	.08						X	X	X	X	X	
Galium obtusum	.16						X	X	X	X	X	
Gentiana andrewsii	.01						X	X	X	X	X	
Glychorriza lepidota	.04						X	X	X	X	X	
Helenium autumnale	.01						X	X	X	X	X	
Helianthus grosseserratus	.79						X	X	X	X		
Helianthus laetiflorus	.03						X	X	X	X		
Helianthus maximiliana	.15						X	X	X	X		
Heliopsis helianthoides	.03						X	X	X	X		
Lactuca scariola	.01						X					
Liatris pycnostachya	.01						X	X	X	X		
Lysimachia chiliata	.05						X	X	X	X	X	
Lythrum alatum	.01						X	X	X	X	X	
Melilotus alba	.05						X					
Mentha arvensis	.03						X	X			X	
Muhlenbergia racemosa	.08						X	X	X	X		
Panicum virgatum	.05						X	X	X	X	X	
Petalostemum purpureum	.01						X	X	X	X		
Phleum pratense	.01						X					
Phlox pilosa	.01						X	X	X	X		
Physalis heterophylla	.15						X	X	X	X		
Physalis virginiana	.01						X	X	X	X		
Poa pratensis	51.03	X					X					X
Polygonum coccineum	.01						X	X			X	
Ratibida columnifera	.12						X	X	X	X		
Rosa blanda	.01						X	X	X	X		
Rosa suffulta	.17						X	X	X	X		
Scirpus atrovirens	.33						X	X			X	
Scutellaria leonardii	.01						X	X	X	X		
Senecio pauperculus	.01						X	X	X	X		
Setaria lutescens	.12						X					
Solidago canadensis	20.97		X				X					X
Solidago rigida	.42						X	X	X	X		
Spartina pectinata	.45						X	X			X	
Sporobolus heterolepis	.06						X	X	X	X		

TABLE 1 (continued)

Species	Ave. % cover	1	2	3	4	5	6	7	8	9	10	11
Teucrium canadense	.03						X	X			X	
Trifolium pratense	.03						X					
Vernonia fasiculata	.01						X	X			X	
Viola pedatifida	.05						X	X	X	X		
Viola sp.	.08						X	X	X	X		
Vicia americana	.01						X	X	X	X		
Zizia aurea	.03						X	X	X	X		

TABLE 2

Beta values and their levels of significance for the fitiing of a quadratic surface to 14 ha of grazed prairie.

Species	Indent. no.	B_0	B_1	B_{11}	B_2	B_{22}	B_{12}	X_3 [a]	X_4 [b]	R^2
Poa pratensis	1	46.45**	5.64**	$.67^{ns}$	5.06**	$-.06^{ns}$	$-.15^{ns}$	-3.99^{ns}	36.95*	.85
Solidago canadensis	2	20.76**	.88*	$.08^{ns}$	$.47^{ns}$	$.06^{ns}$	$-.04^{ns}$	-1.32^{ns}	-20.11**	.57
Andropogon gerardii	3	44.05**	-6.16**	-1.02*	-3.27**	$.16^{ns}$	$-.06^{ns}$	-9.02^{ns}	-25.15^{ns}	.73
Aster ericoides	4	1.35**	$.01^{ns}$	$-.04^{ns}$	$-.06^{ns}$	$.01^{ns}$	$.02^{ns}$	$.19^{ns}$	$-.54^{ns}$	.12
Ambrosia artemisifolia	5	$.28^{ns}$	$.06^{ns}$	$.02^{ns}$	$-.02^{ns}$	$.01^{ns}$	$.00^{ns}$	$.45^{ns}$	1.94^{ns}	.09
Number of species	6	9.26**	$-.32^{ns}$	$-.04^{ns}$	$-.11^{ns}$	$.06^{ns}$	-.05	4.58**	$-.54^{ns}$	.61
All prairie species	7	3.36**	$-.15^{ns}$	$.06^{ns}$	-.44**	$.02^{ns}$	$-.03^{ns}$	5.63**	-5.48^{ns}	.78
High prairie species	8	2.03*	-.34*	$.03^{ns}$	$-.20^{ns}$	$-.02^{ns}$	$.01^{ns}$	3.41**	2.35^{ns}	.66
Andropogon gerardi and high prairie species	9	47.42**	-6.66**	-.95*	-3.72**	$-.23^{ns}$	$.06^{ns}$	-5.48^{ns}	-22.71^{ns}	.76
Low prairie species	10	$-.02^{ns}$	$-.10^{ns}$	$.04^{ns}$	$-.13^{ns}$	$.03^{ns}$	$.04^{ns}$	3.83**	$-.82^{ns}$	.85
Solidago canadensis and Poa pratensis	11	63.77**	7.07**	.79*	5.59**	$.17^{ns}$	$-.36^{ns}$	-5.31^{ns}	16.85^{ns}	.86

[a] Drainage

[b] Cirsium arvense

** Significant at the 1% level

* Significant at the 5% level

ns nonsignificant

these species, and recovery from grazing disturbance using only natural seed sources after 25 years of being ungrazed, in the 14 ha grazed area of Kalsow Prairie.

METHODS

The vegetation of the grazed portion of Kalsow Prairie was analyzed using two separate approaches. The first involved the identification and listing of all plant species found within its boundaries. The second involved dividing the area into 30 equal-sized blocks (each block measuring 60 m by 78 m and then sub-sampling each block using a 20 cm x 50 cm quadrat placed at 3-m intervals along an S-shaped transect. Cover estimates were made for each quadrat using Daubenmire's (1959) cover class method.

Coverage was determined separately for all species overlapping the plot regardless of where the individuals were rooted. Coverage was projected to include the perimeter of overlap of each species regardless of superimposed canopies of other species. The canopies of different species are commonly interlaced or superimposed over the same area, and therefore coverage percents often total greater than 100 percent.

A quadratic surface was then fitted to summary data in an attempt to discover the direction of movement of prairie plants into the grazed area. The statistical model used in this analysis was as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_{11} X_1^2 + \beta_2 X_2 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 + \varepsilon_i$$

where: Y = estimated mean value from the regression of average cover data
β = population regression coefficient
ε = error variable

and
X_1 = north-south direction variable
X_2 = east-west direction variable

RESULTS AND DISCUSSION

The state of the vegetation on the grazed portion of Kalsow Prairie in 1949 is unknown since no studies or descriptions were made of it at that time. However, Weaver (1954) indicates that prairies, when subjected to grazing over long periods of time, tend to degenerate. He states that under grazing conditions the prairie flora is generally impoverished and replaced by species which are better adapted to the pressure of close grazing and trampling. Such plants are generally referred to as increasers, and in the present case include Poa pratensis, Solidago canadensis, Verbena stricta and several other inedible forbs of the region. Field observations near Kalsow Prairie on several pastures used for grazing support Weaver's (1954) conclusions. Therefore, it seems that the 1949 pasture vegetation could well have been dominated by Poa pratensis, Solidago canadensis, and Verbena stricta. The cover values from Table 1 support this conclusion.

Aerial photographs taken in 1968 (Fig. 2) of Kalsow Prairie indicate that vegetation patterns along the old 1949 fence lines which separated the grazed portion from the prairie proper were still visible. Thus, the rather sharp lines of demarcation between the grazed pasture and the adjacent prairie vegetation in 1949 were, some 19 years later, still in existence. The pasture at present (1976), however, as in 1968, includes as part of its vegetation many prairie species (Table 1).

Investigation of the successful invasion of prairie species into the pasture was accomplished by dividing the pasture into 30 equal-sized blocks and then sub-sampling the vegetation of each block. An analysis of a quadratic surface fitted to eleven treatments (Tables 1 and 2) in attempts to define as nearly as possible the influx into the pasture of prairie species showed (Table 2) nine of the eleven treatments possess R^2 values greater than .57. Data from Table 2, used to construct diagrams (Fig. 3) of the fitted surfaces, indicate that there has been a definite movement of prairie species into the pasture. Figures 3b and 3c show this movement. Figure 3b represents the fitted surface on the average cover values of Andropogon gerardi, and Figure 3c represents a fitted surface on composite average cover values of all native prairie species found within the pasture except Andropogon gerardi and Solidago canadensis. Other treatments showing this same kind of surface were 8 (high prairie species) and 9 (Andropogon gerardi-high prairie species) (Table 1). Figure 3a is the fitted surface of average cover values of Poa pratensis. This figure is almost a mirror image of the surface representing the advance of Andropogon gerardi; thus it is interpreted to represent the retreat of Poa pratensis. Figures 3d, 3e, and 3f represent fitted surfaces for treatments of average cover values for low prairie species, number of species, and average cover values for Ambrosia artemisifolia (Table 2). Of these treatments "low prairie" represents a composite of all species common to the drainage areas of native prairie vegetation (Table 1). No suggestion of directional movements of these lowland species can be seen in Figure 3d, but it is interesting to note that the R^2 value for this treatment is .85 and that the treatment is also highly correlated with the drainage factor. The "number of species" treatment shows that the areas nearest the prairie-pasture boundary do not exhibit greater numbers of species than areas away from the prairie. From Figures 3e and Table 1 it seems that diversity is more closely related to the presence of drainage ways than to the proximity of sites to the prairie-pasture border.

Field observations indicated that there existed an apparent front of the Andropogon gerardi influx into the old pasture. It was of interest to know if this front was an invasion front dependent on time or if it was being restricted in its present position by some environmental factor. A contour map, extrapolated from the average cover values of Andropogon gerardi as found within each of the original 30 units (Fig. 4), shows the distribution of Andropogon gerardi as a wave front extending into the pasture from the pasture-prairie border. It seems likely that the observed front is an actual invasion apart from the restriction of environmental factors.

It appears, then, that the prairie is in the processes of reestablishing itself within the boundaries of the 14 ha of old pasture. The process is slow as evidenced by old fence lines which were still very visible in 1968 and by the fact that Andropogon gerardi makes up about 90% of the cover given to the area by prairie species. In another ten years it is likely that the area will be completely dominated by Andropogon gerardi, but it seems doubtful that the area will return to the vegetation type now represented by the major portion of Kalsow Prairie in the next 100 years.

LITERATURE CITED

Aikman, J. M. 1959. Prairie research in Iowa. Amer. Biol. Teacher 21:7-8.

Brennan, K. M. 1969. Vertebrate fauna of Kalsow Prairie. M.S. thesis, Iowa State Univ.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-66.

Dick-Peddie, W. A. 1955. Presettlement forest types in Iowa. Ph.D. dissertation, Iowa State Univ. 76 p.

Dondore, D. A. 1926. The prairie and the making of middle America: Four centuries of description. Cedar Rapids, Iowa, The Torch Press. 472 p.

Ehrenreich, J. H. 1957. Management practices for maintenance of native prairies in Iowa. Ph.D. Dissertation, Iowa State Univ.

Esau, K. L. 1968. Carabidae (Coleoptera) and other arthropods collected in pitfall traps in Iowa cornfields, fencerows and prairies. Ph.D. dissertation, Iowa State Univ.

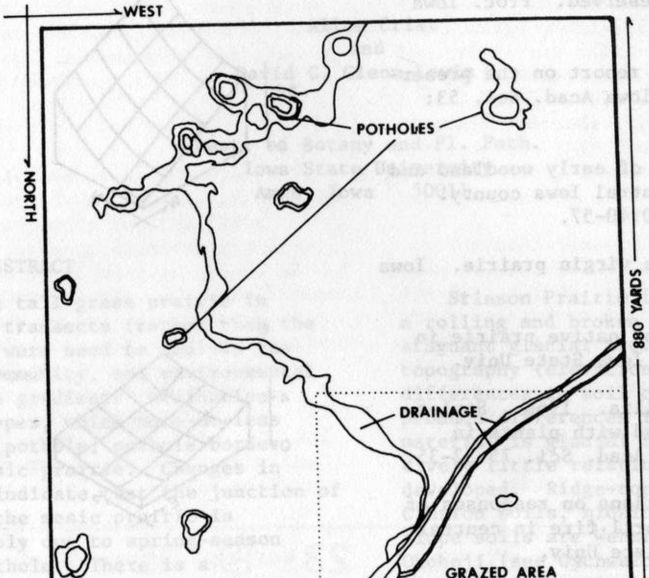


Fig. 1. Map of Kalsow Prairie showing locations of potholes, drainage, and 14 ha grazed area.

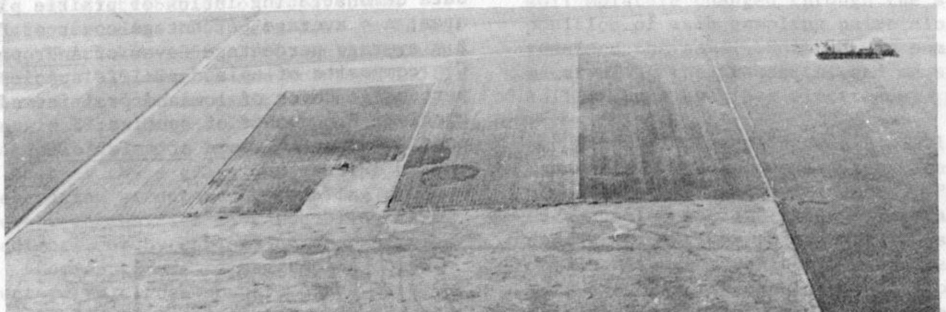


Fig. 2. Aerial photograph of western half of Kalsow Prairie (facing south), showing old fence line and drainage pattern in the grazed pasture in foreground.

Hayden, Ada. 1945. The selection of prairie areas in Iowa which should be preserved. Proc. Iowa Acad. Sci. 52:127-148.

Hayden, Ada. 1946. A progress report on the preservation of prairie. Proc. Iowa Acad. Sci. 53: 45-82.

Hewes, L. 1950. Some features of early woodland and prairie settlement in a central Iowa county. Ann. Assoc. Amer. Georg. 40:40-57.

Landers, R. Q. 1966. Visit the virgin prairie. Iowa Farm Sci. 21:418-419.

Moyer, John F. 1953. Ecology of native prairie in Iowa. Ph.D. dissertation, Iowa State Univ.

Norton, D. C., and P. E. Ponchillia. 1968. Stylet-bearing nematodes associated with plants in Iowa prairies. Proc. Iowa Acad. Sci. 75:32-35.

Richards, M. S. 1969. Observations on responses of prairie vegetation to an April fire in central Iowa. M.S. thesis, Iowa State Univ.

Schmitt, D. P. 1969. Plant parasitic nematodes and nematode populations in the Kalsow Prairie. M.S. thesis. Iowa State Univ.

U.S. Government. 1868. First survey of the State of Iowa. Plats deposited in the State House, Des Moines, Iowa.

Weaver, J. E. 1954. North American Prairie. Lincoln, Nebraska, Johnsen Publ. Co. 348 p.

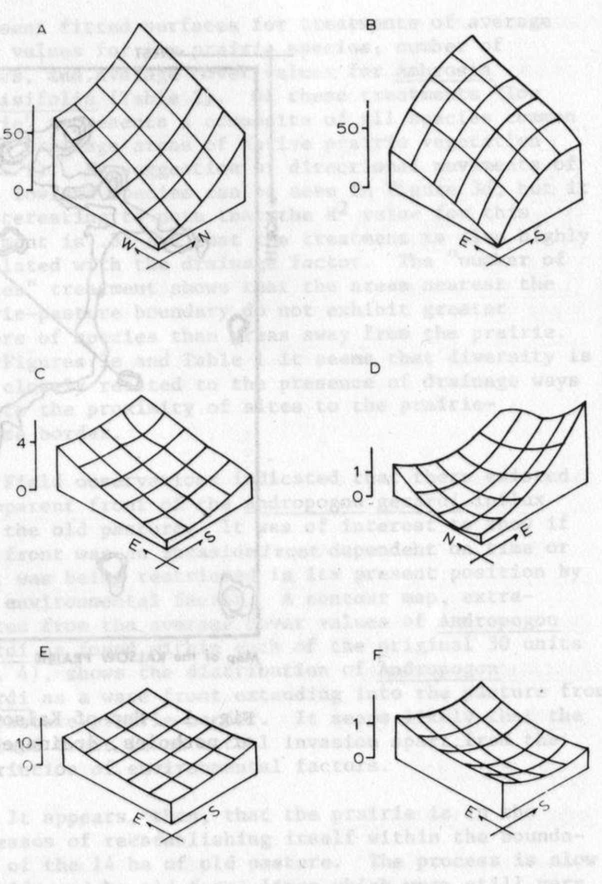


Fig. 3. Fitted quadratic surfaces of grazed pasture data demonstrating influx of prairie plants into the area; A = average percentage cover of Poa pratensis; B = average percentage cover of Andropogon gerardi; C = composite of upland prairie species; D = average percentage cover of lowland prairie and drainage species; E = number of species; F = average percentage cover of Ambrosia artemisifolia.

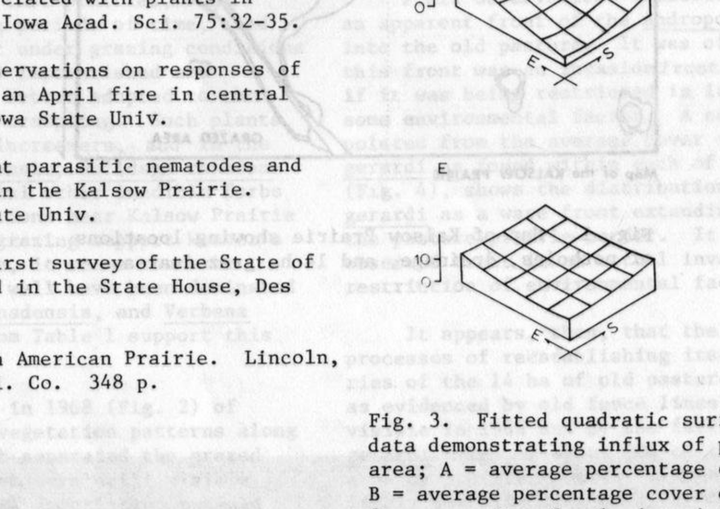


Fig. 4. Andropogon gerardi invasion of grazed pasture indicated by lines representing percentage cover values.

THE STRUCTURE OF COMMUNITY AND ENVIRONMENTAL GRADIENTS IN A NORTHERN IOWA PRAIRIE

Allan Crist
and
David C. Glenn-Lewin

Dept. of Botany and Pl. Path.
Iowa State University
Ames, Iowa 50011

ABSTRACT

On Stinson Prairie, a tall-grass prairie in northern Iowa, replicate transects (rather than the usual scattered samples) were used to analyze the structure of the plant community, and environmental correlates, along a slope gradient. Ordination reveals four community types, which more-or-less grade into one another: pothole, pothole border, mesic prairie and dry-mesic prairie. Changes in vegetational similarity indicate that the junction of the pothole border with the mesic prairie is relatively abrupt, probably due to spring-season standing water in the pothole. There is a moderately rapid species turnover between the dry-mesic and mesic prairies. Soil moisture appears to be the most important environmental factor. Dominance-diversity curves indicate that species diversity and community complexity decreases from the upland prairies into the pothole.

INTRODUCTION

Since the exposition of the principle of species individuality (Gleason 1926, Ramensky 1924), the development of techniques of gradient analysis and ordination has produced useful tools for the analysis of the structure and distribution of vegetation. Many such vegetation studies have been done in forest vegetation (e.g., Whittaker 1956, 1960; Whittaker and Niering 1965; Curtis 1959; Curtis and McIntosh 1951). Fewer studies have been done in prairies and grasslands (e.g., Curtis 1955; Knight 1965; Ayyad and Dix 1964; Dix and Butler 1960; Dix and Smeins 1967; Baines 1973). Most of these grassland studies have investigated vegetation structure by sampling a number of different communities and assembling them on presumed gradients, or by subjecting such samples to ordination. Common trends of vegetation composition and structure were then sought, along with environmental variables that correlated with vegetation patterns. The present study, on the other hand, is an analysis of the vegetation composition and structure of tall-grass prairie along a physically continuous coenocline, extending from dry prairie into a prairie pothole. Specifically, we investigated: (1) the structure of the coenocline and species distribution, (2) any tendency to form community units, and if so, to what degree, (3) the environmental correlates of vegetation distribution, and (4) changes in species diversity along the coenocline. The present paper is a preliminary report of the results.

The study area was Stinson Prairie, an Iowa state prairie preserve of about 12.5 ha located in southern Kossuth Co. about 8 km west of Algona. The area has cold winters (mean Jan. temperature -8.5 C) and warm summers (mean July temperature 23.2 C). Precipitation is moderate (769 mm) but variable, most (74%) falling in the summer.

Stinson Prairie is located on the Algona moraine, a rolling and broken recessional moraine caused by stagnant glacial ice. Because of this rolling topography (elevation difference 15 m) substantial differences in soil conditions exist, which, in turn, produce differences in vegetation. The soil parent material is glacial till, although this bears relatively little relationship to the soils as they have developed. Ridge-top and upper-slope soils are Clarion soils, midslope soils are Nicolett, and lower slope soils are Webster. Pothole soils are Harps and Okoboji (see Oschwald et al 1965). These soils form a catena from relatively thin, well-drained soils on the hill-tops to thick, organic, alluvial soils in the prairie potholes. A description of the prairie and a list of species is given in Glenn-Lewin (1976).

METHODS

The basic sample layout was a series of three replicate 94 m transects running from a dry ridge-top into the center of a pothole. Soil moisture was sampled and measured gravimetrically every third meter along each of the transects several times throughout the growing season. Although the absolute amount of soil moisture changed through the seasons, the relative position of each sampling point along the transect remained the same. Soil pH was sampled every sixth meter along the transects, and measured in a 2:1 water soil mixture by glass electrodes.

Vegetation sampling was done along all three transects. Vegetation samples were 1 m^2, placed every other meter along the transects. Percent cover for each species was estimated. Vegetation sampling was done several times throughout the seasons in order to obtain maximum coverage by each species. The transects were averaged for each distance along the transect. This results in a "composite transect"; any one point along the composite transect is an average of 3 quadrats, and this average point can be termed a "composite quadrat".

Nomenclature follows Pohl (1966) for grasses, Gilly (1946) for the Cyperaceae, and Gleason (1952) for the rest. Sampling was carried out during the 1975 and 1976 growing seasons.

RESULTS AND DISCUSSION

Substrate.

Soil moisture recorded on 15 July 1976 is shown as the percent of dry weight in Fig. 1. This soil moisture profile is typical for all the soil moisture profiles taken throughout the study period. Soil moisture tends to be very low on the crests of the hills, and increases downward to the pothole where soil moisture is generally high and the soil often saturated; there is usually standing water in the pothole in the spring. Soil pH is shown in Fig. 2.

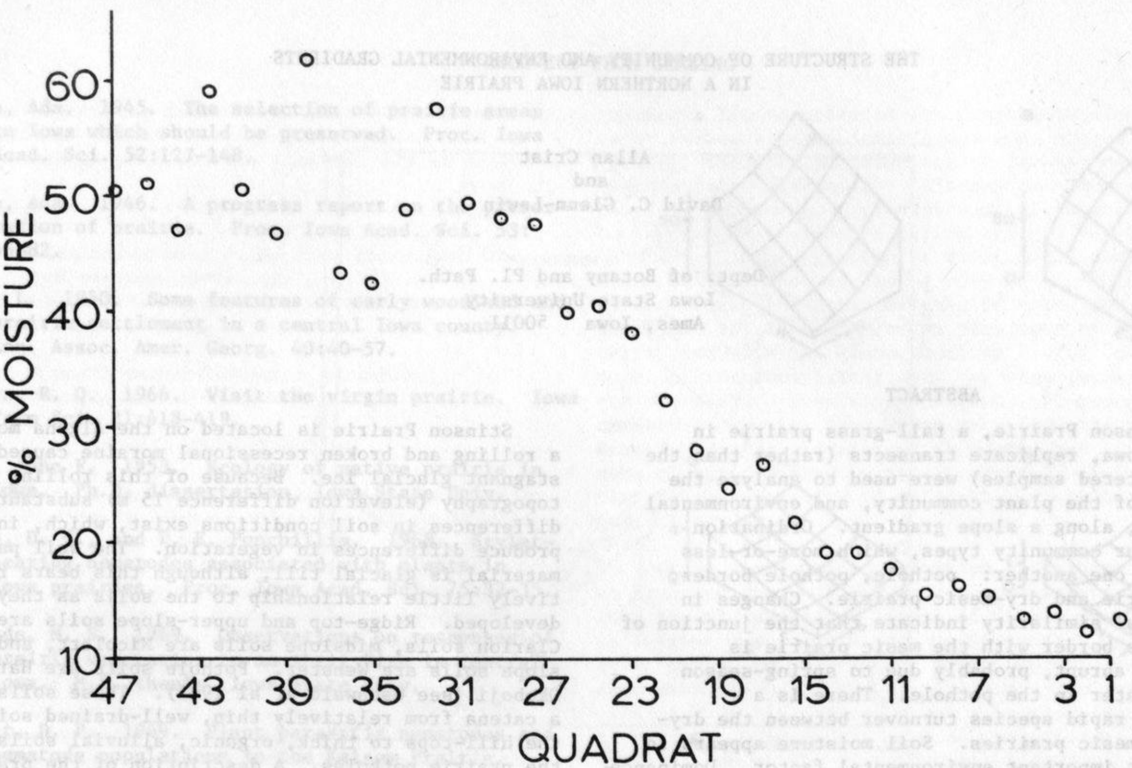


Fig. 1. Representative soil moisture, as per cent of dry weight, from Stinson Prairie, 15 July 1976. Quadrat No. 1 was the upper extreme of the transect; No. 47 was the pothole center.

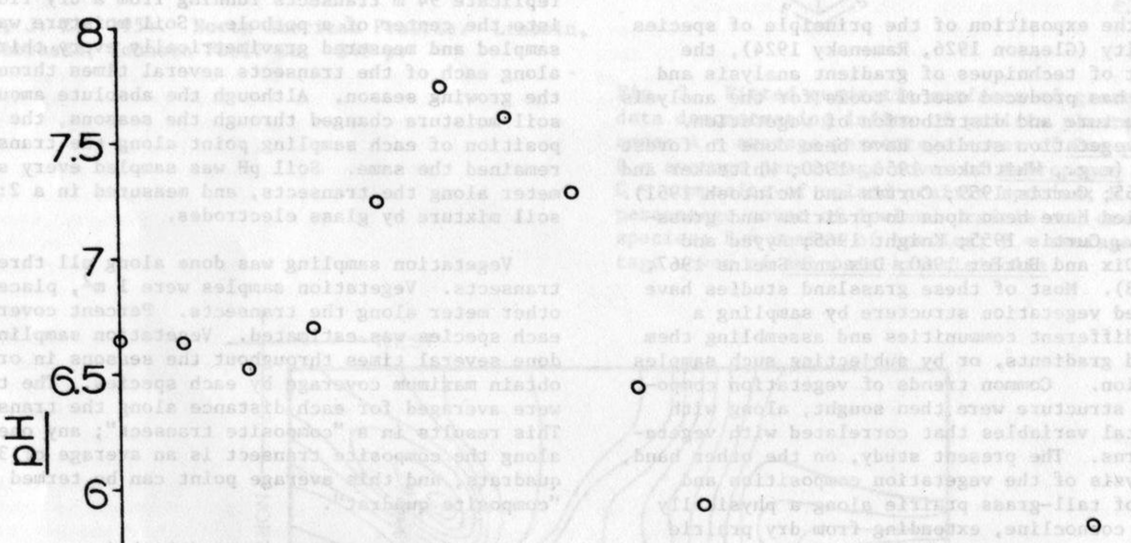


Fig. 2. Soil pH along the composite transect, Stinson Prairie. Quadrat No. 1 was the upper extreme of the transect; No. 47 was the pothole center.

pH is low on the hills and upper slopes (pH 5.0 - 5.7) due to leaching. pH increases downslope to its highest point at the pothole edge (7.7), where there is a recharge of calcium at the soil surface by upward capillary movement of water. Inside this pothole edge soil pH is somewhat lower (6.6).

Vegetation

A Bray-Curtis ordination (Bray and Curtis 1957) using the composite quadrats from the ends of the transect (No. 1, 47) as endpoints for the first ordination axis, and the two most dissimilar stands from the center 10% of the first axis as endpoints for the second axis, is shown in Fig. 3. The distance, or division, between stands 34 and 36 is obvious. This rapid change in communities correlates with the high water mark or edge of the pothole along the coenocline. The Bray-Curtis ordination in Fig. 3 indicates some sorting of the upland stands (No. 1-34) into two groups (communities C and D in Fig. 3), and there is also some degree of separation between the center of the pothole (A in Fig. 3) and the pothole border (B in Fig. 3).

The four vegetation types determined from the ordination are shown along a cross-section of the coenocline in Fig. 4. Communities A - D correspond to the same communities in the ordination (Fig. 3). The four communities along with their most important species are listed below.

A. Pothole: Scirpus fluviatilis, Polygonum coccineum, Carex lacustris.
B. Pothole border: Polygonum coccineum, Spartina pectinata, Calamagrostis canadensis, Poa palustris, Carex stricta.
C. Mesic prairie: Aster simplex, Desmodium canadense, Elymus canadensis, Panicum virgatum, Helianthus grosseserratus, Pycnanthemum virginianum, Ratibida pinnata, Silphium laciniatum, Sorghastrum nutans.
D. Dry-mesic prairie: Amorpha canescens, Andropogon gerardii, A. scoparius, Baptisia leucophea, Coreopsis palmata, Helianthus laetiflorus, Lespedeza capitata, Panicum scribnerianum, Rosa sp., Zizia aurea, Stipa spartea.

Although the ordination shown in Fig. 3 is two-dimensional, the first axis accounts for most of the variation. This axis is defined by the transect endpoints, which are the extremes of the topographic gradient. This topographic gradient is a presumed determinant of the soil moisture gradient shown in Fig. 1. Several other gradient analyses of prairie vegetation have also emphasized the importance of the topographic moisture gradient (Baines 1973, Dix 1958, Dix and Smeins 1967, Curtis 1955, Knight 1965, Ayyad and Dix 1964). However, all of these studies have been syntheses of stands scattered across the landscape, whereas the significance of the topographic moisture gradient demonstrated in the present study is illustrated along a continuous transect.

To illustrate the degree of community continuity or discontinuity along the coenocline, average percent similarity for each composite quadrat with its nearest four neighbors, two on either side, was calculated and plotted in Fig. 5. There is no point along the coenocline where average similarity with neighboring quadrats is near zero. However, there are two points where average similarity is relatively low. These are around composite quadrats 23 and 35. The first is the relative discontinuity between upland dry-mesic prairie and lower-slope mesic prairie. The low average similarity at quadrat 35 is indicative of the relatively rapid turnover of species occurring at the prairie pothole border. Thus, although the four prairie communities along the coenocline are not discretely bounded, they do show relative discontinuity with neighboring communities as evidenced by the relatively rapid change in species composition between them.

The basic continuity of prairie vegetation has been emphasized by Curtis (1955), Dix (1958), Dix and Smeins (1967) and Knight (1965), as well as by the results from Stinson Prairie. However, a relatively rapid turnover in species composition between the upland prairie and lower meadows and marshes, such as observed on Stinson Prairie (Fig. 5), was also noted by Dix and Smeins (1967). Beschel and Webber (1962) found a similar situation in swamp forests. Standing water and water-level fluctuations are the likely explanations for these observations (Walker and Coupland 1968, Kadlec 1962, Dix and Smeins 1967). Redmann (1972), noting a vegetation difference associated with abrupt changes in substrate salinity, concluded that prairie community boundaries were gradual or marked, depending upon whether change along the associated environmental gradient was gradual or marked.

The average number of species per composite quadrat (species richness) is shown in Fig. 6. Richness is roughly the same through the dry-mesic and mesic prairie, but drops precipitously at the pothole border to only three species per composite quadrat in the pothole. The lack of richness difference between the dry-mesic and mesic prairies contrasts with the finding of increased numbers of species in the mesic prairie by Glenn-Lewin (1976). This discrepancy probably comes about because the present samples are composites of three one-meter square samples, whereas the data in Glenn-Lewin (1976) were composites of 15 one-meter square samples.

Dominance-diversity curves (Whittaker 1965) illustrate the combined change in numbers of species and relative abundance along the coenocline (Fig. 7). In Fig. 7, stand 13 represents the dry-mesic prairie, 23 the mesic prairie, 37 the pothole edge and 45 the pothole center. From these selected composite quadrats, it can be seen that the upland prairies (dry-mesic and mesic) are characterized by the sigmoid curves typical of rich, even plant communities, whereas the pothole border and the pothole proper are characterized by the steeper straight-line curves characteristic of species poor, and strongly dominated, plant communities (Whittaker 1965, 1969, 1975; McNaughton 1968; see also Pielou 1975). Field data from other studies show conflicting trends for diversity (Glenn-Lewin 1976), except that diversity is generally low in swales and potholes (Glenn-Lewin 1976, Bliss and Cox 1964).

More complete data on soils and environmental correlations, based on two field seasons, will be reported later. A survey of the pothole and edge vegetation with respect to elevation, as well as distance along the transects, will also be presented elsewhere.

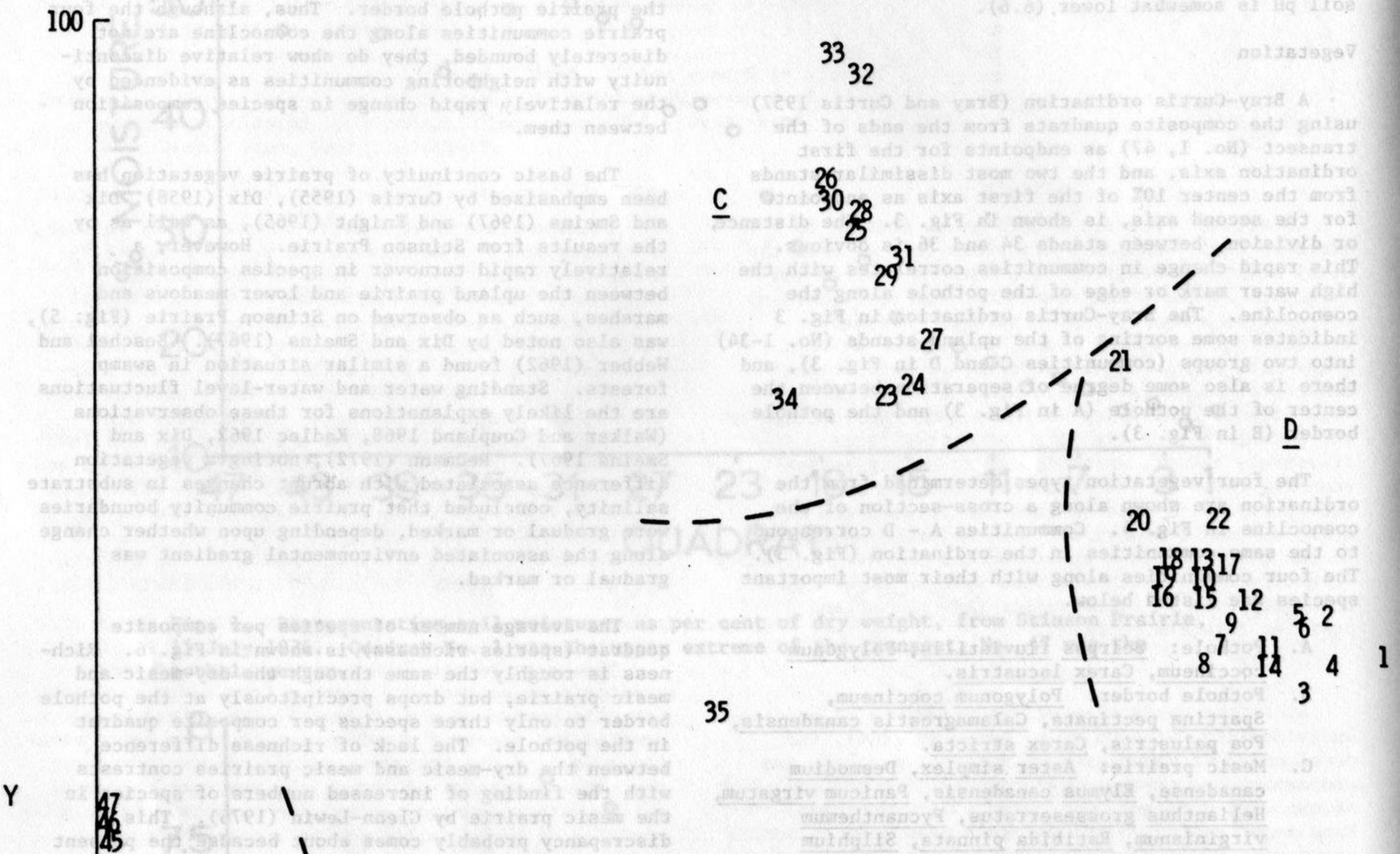


Fig. 3. Bray-Curtis ordination of the vegetation along the Stinson Prairie composite transect. The first axis is defined by the transect extremes; No. 1 was the upper extreme of the transect; No. 47 was the pothole center. A - pothole, B - pothole border, C - mesic prairie, D - dry-mesic prairie.

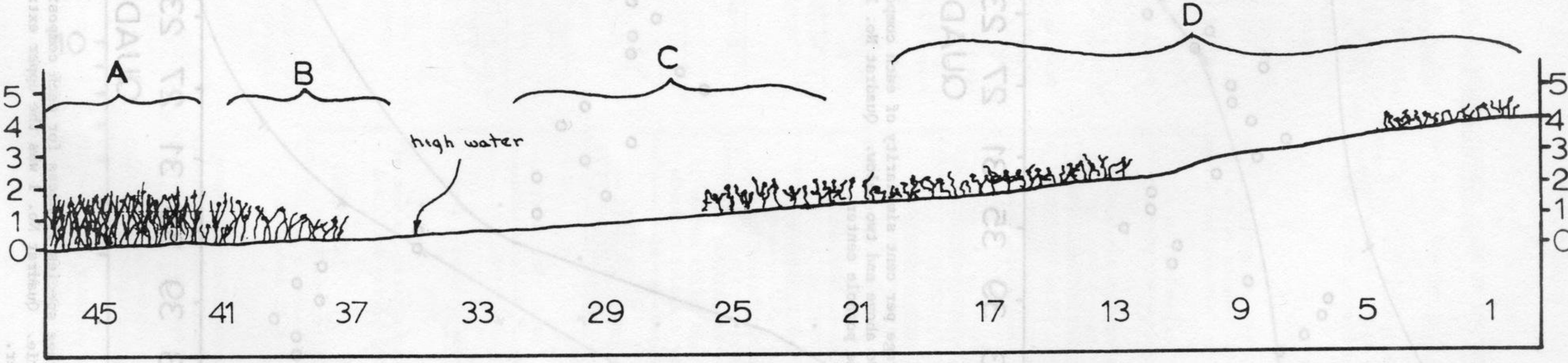


Fig. 4. Vegetation gradient cross-section along the Stinson Prairie composite transect. Quadrat numbers start at the upper elevation of the transect. A - pothole, B - pothole border, C - mesic prairie, D - dry-mesic prairie.

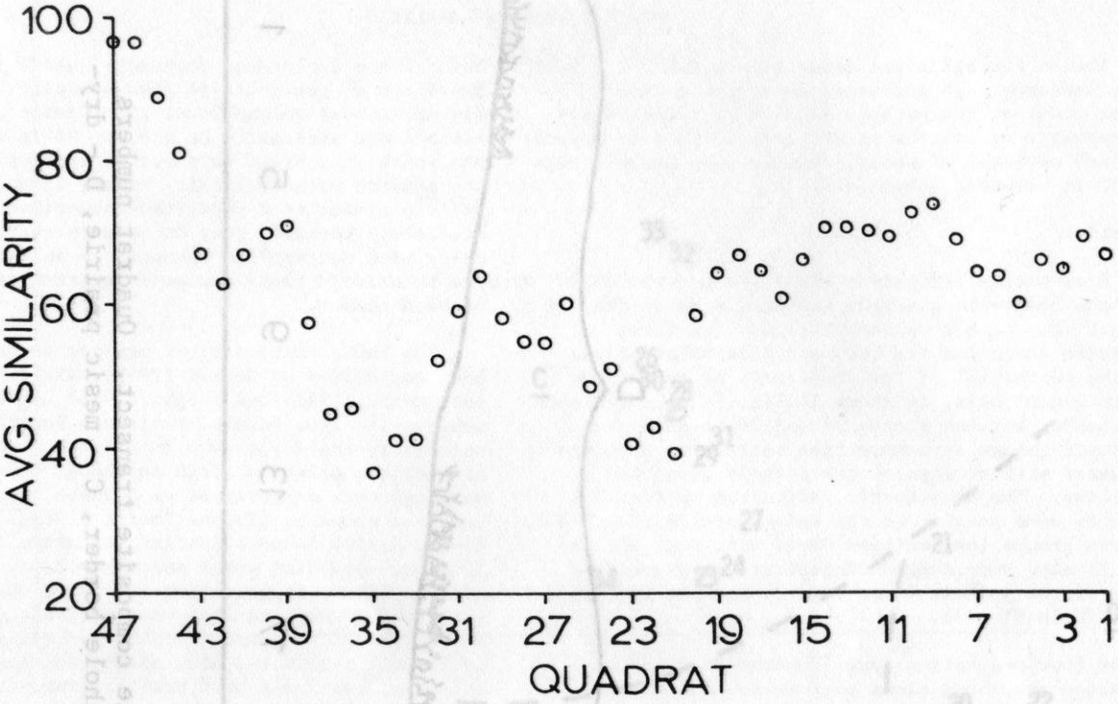


Fig. 5. Average per cent similarity of each composite sample with its nearest four neighbors, two above and two below. Quadrat No. 1 was the upper extreme of the transect; No. 47 was the pothole center.

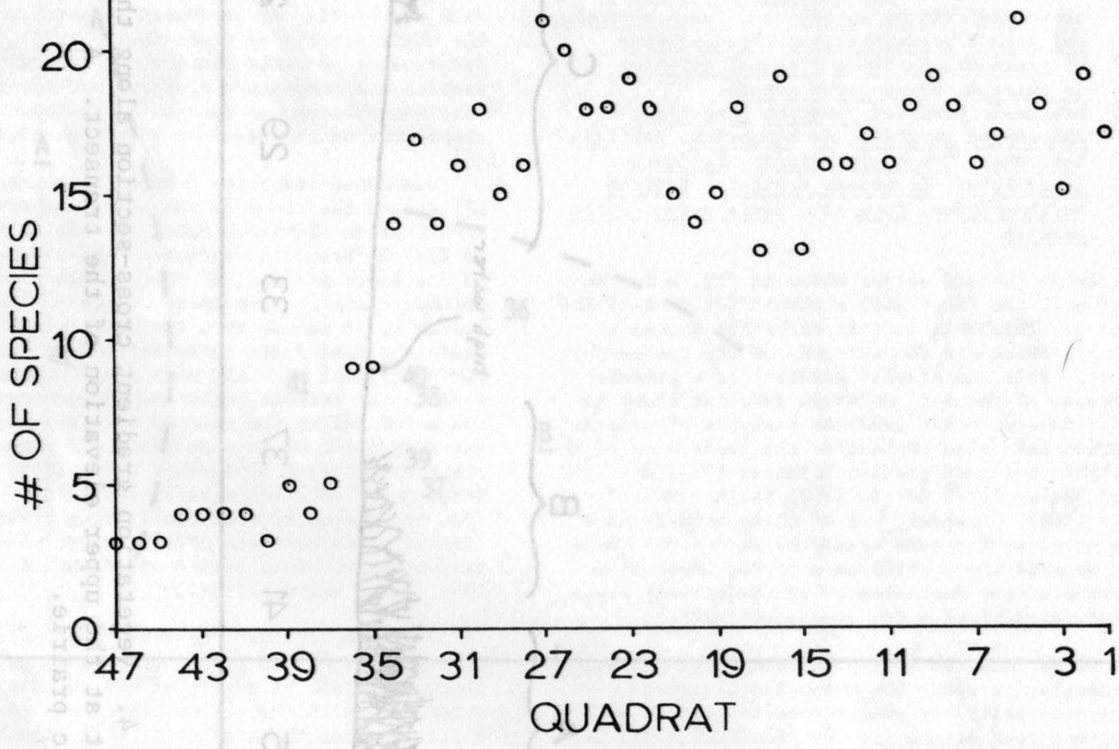


Fig. 6. Average species richness for each composite sample along the slope gradient of Stinson Prairie. Quadrat No. 1 was the upper extreme of the transect; No. 47 was the pothole center.

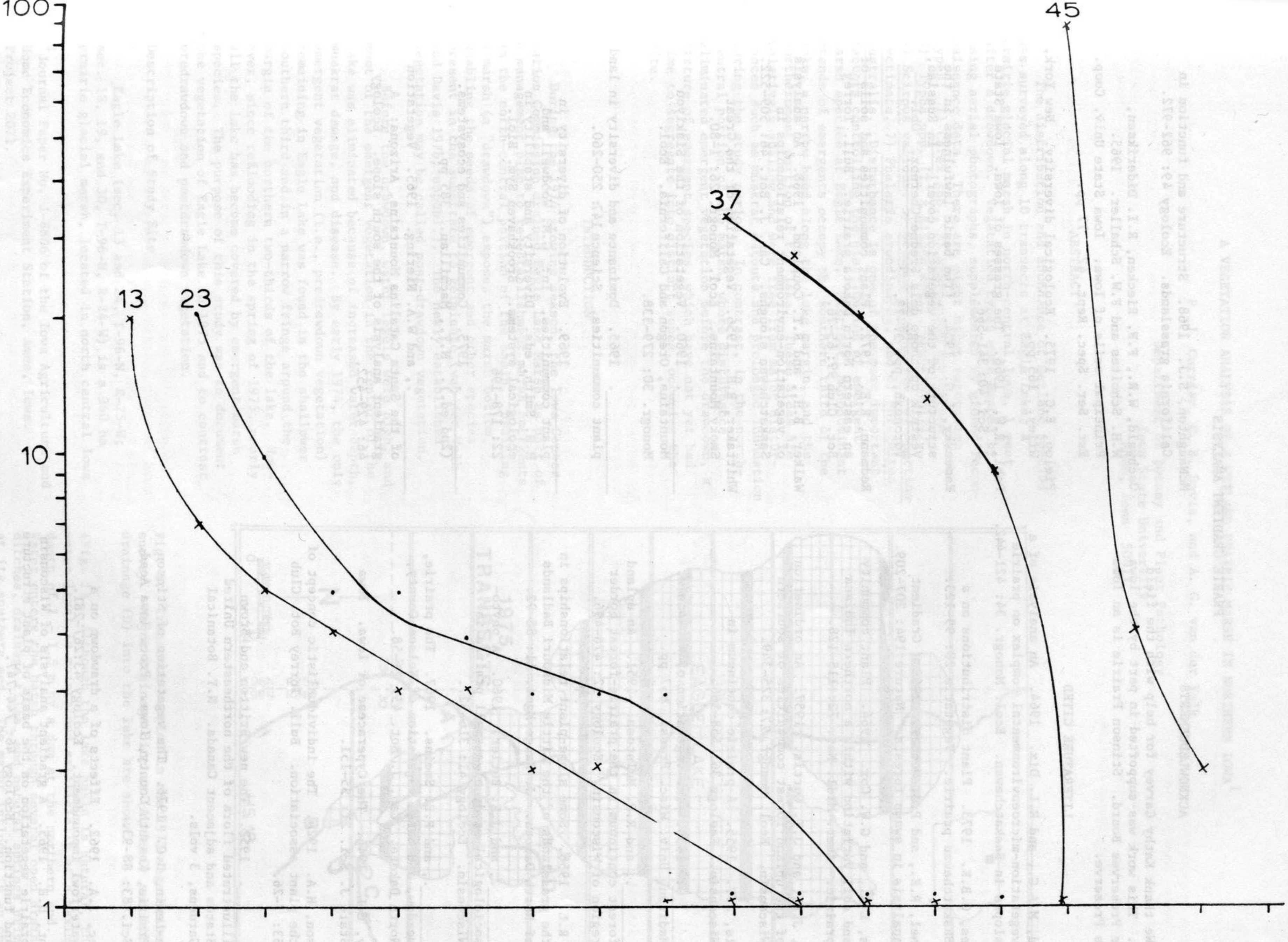


Fig. 7. Dominance-diversity curves from representative composite samples along the Stinson Prairie slope gradient. Sample No. 13 - dry-mesic prairie; No. 23 - mesic prairie; No. 37 - pothole border; No. 45 - pothole center.

ACKNOWLEDGEMENTS

We thank Kathy Carvey for help with the field work. This work was supported in part by the Iowa State Preserves Board. Stinson Prairie is an Iowa State Preserve.

LITERATURE CITED

Ayyad, M.A.G., and R.L. Dix. 1964. An analysis of a vegetation-microenvironmental complex on prairie slopes in Saskatchewan. Ecol. Monogr. 34: 421-442.

Baines, G.B.K. 1973. Plant distributions on a Saskatchewan prairie. Vegetatio 28: 99-123.

Beschel, R.E., and P.J. Webber. 1962. Gradient analysis in swamp forests. Nature 194: 207-209.

Bliss, L.C., and G.W. Cox. 1964. Plant community and soil variation within a northern Indiana prairie. Amer. Midl. Nat. 72: 115-128.

Bray, J.R., and J.T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325-349.

Curtis, J.T. 1955. A prairie continuum in Wisconsin. Ecology 36: 558-566.

___________. 1959. The vegetation of Wisconsin. Madison, Univ. Wisc. Press. 657 pp.

___________., and R.P. McIntosh. 1951. An upland forest continuum in the prairie-forest border region of Wisconsin. Ecology 32: 476-496.

Dix, R.L. 1958. Some slope-plant relationships in the grasslands of the Little Missouri Badlands of North Dakota. J. Range Mgmt. 11: 88-92.

___________., and J.E. Butler. 1960. A phytosociological study of a small prairie in Wisconsin. Ecology 41: 316-327.

___________., and F.E. Smeins. 1967. The prairie, meadow, and marsh vegetation of Nelson County, North Dakota. Can. J. Bot. 45: 21-58.

Gilly, C.L. 1946. The Cyperaceae of Iowa. Iowa State J. Sci. 21: 55-151.

Gleason, H.A. 1926. The individualistic concept of the plant association. Bull. Torrey Bot. Club 53: 7-26.

___________. 1952. The new Britton and Brown illustrated flora of the northeastern United States and adjacent Canada. N.Y. Botanical Gardens, 3 vols.

Glenn-Lewin, D.C. 1976. The vegetation of Stinson Prairie, Kossuth County, Iowa. Proc. Iowa Acad. Sci. 83: 88-93.

Kadlec, J.A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43:267-281.

Knight, D.H. 1965. A gradient analysis of Wisconsin prairie vegetation on the basis of plant structure and function. Ecology 46: 744-747.

McNaughton, S.J. 1968. Structure and function in California grasslands. Ecology 49: 962-972.

Oschwald, W.R., F.F. Riecken, R.I. Dideriksen, W.H. Scholtes and F.W. Schaller. 1965. Principal soils of Iowa. Iowa State Univ. Coop. Ext. Ser. Spec. Rept. 42. 77 pp.

Pielou, E.C. 1975. Ecological diversity. New York, Wiley. 165 pp.

Pohl, R.W. 1966. The grasses of Iowa. Iowa State J. Sci. 40: 341-566.

Ramensky, L.G. 1924. [The basic lawfulness in the structure of the vegetation cover]. In Russian, Věstnik opȳtnogo dêla Sredne-Chernoz. Obl. Voronezh, pp. 37-73.

Redmann, R.E. 1972. Plant communities and soils of an eastern North Dakota prairie. Bull. Torrey Bot. Club 99: 65-76.

Walker, B.H., and R.T. Coupland. 1968. An analysis of vegetation-environment relationships in Saskatchewan sloughs. Can. J. Bot. 46: 509-522.

Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecol. Monogr. 26: 1-80.

___________. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecol. Monogr. 30: 279-338.

___________. 1965. Dominance and diversity in land plant communities. Science 147: 250-260.

___________. 1969. Evolution of diversity in plant communities. In: G.M. Woodwell and H.H. Smith, eds. Diversity and stability in ecological systems. Brookhaven Sym. Biol. 22: 178-196

___________. 1975. Communities and ecosystems. (2nd ed.). N.Y., Macmillan. 385 pp.

___________., and W.A. Niering. 1965. Vegetation of the Santa Catalina Mountains, Arizona: A gradient analysis of the south slope. Ecology 46: 429-452.

A VEGETATION ANALYSIS OF A WETLAND PRAIRIE MARSH IN NORTHERN IOWA[1]

P. J. Currier, C. B. Davis, and A. G. van der Valk

Department of Botany and Plant Pathology
Iowa State University
Ames, Iowa 50011

ABSTRACT

The distribution and abundance of wetland species was surveyed along 10 transects at Eagle Lake, a prairie glacial marsh in north-central Iowa, 1 year after a drawdown. Vegetation types were mapped by using aerial photographs, supplemented by ground reconnaissance data. There are eight major vegetation types: 1) Carex spp., 2) Sparganium eurycarpum, 3) Typha spp. (T. x glauca and T. angustifolia), 4) Scirpus validus, 5) Scirpus fluviatilis, 6) Spartina pectinata, 7) Phalaris arundinacea, and 8) Phragmites australis. Disturbance is one of the most important factors controlling the distribution of emergent marsh species at Eagle Lake. Distinct, monodominant stands of emergents occupy the southern third of the lake, a narrow band along the lake margin, and the northernmost portion of the lake. These areas are relatively shallow and were free from major disturbances such as muskrat eatouts and prolonged inundation during the study period. In contrast, in the north-central portion of the marsh, where disturbance eliminated emergent vegetation before the drawdown, a mixture of emergent species, which have not yet had time to segregate into distinct zones, occupies the site.

INTRODUCTION

During the 1974 growing season, the Iowa Conservation Commission drained Eagle Lake Marsh as part of a management plan to re-establishment marsh emergents in the north-central portion of the basin. Draining a marsh (a "drawdown") exposes the marsh bottom, enabling the seeds of emergent and other species present in the substrate to germinate (van der Valk and Davis 1976; unpubl.). The newly established vegetation may be called post-drawdown vegetation.

Before the drawdown, water levels were high, and most of the emergent vegetation in the center of the lake was eliminated because of increased water depth, muskrat damage, and disease. By early 1974, the only emergent vegetation (i.e., predrawdown vegetation) remaining in Eagle Lake was found in the shallower southern third and in a narrow fringe around the margin of the northern two-thirds of the lake. However, since reflooding in the spring of 1975, nearly all the lake has become covered by emergent marsh species. The purpose of this study was to document the vegetation of Eagle Lake in 1975 and to contrast predrawdown and postdrawdown vegetation.

Description of Study Site

Eagle Lake (sec. 13 and 24, T-96-N, R-25-W; sec. 18, 19, and 30, T-96-N, R-24-W) is a 360 ha prairie glacial marsh, located in north central Iowa

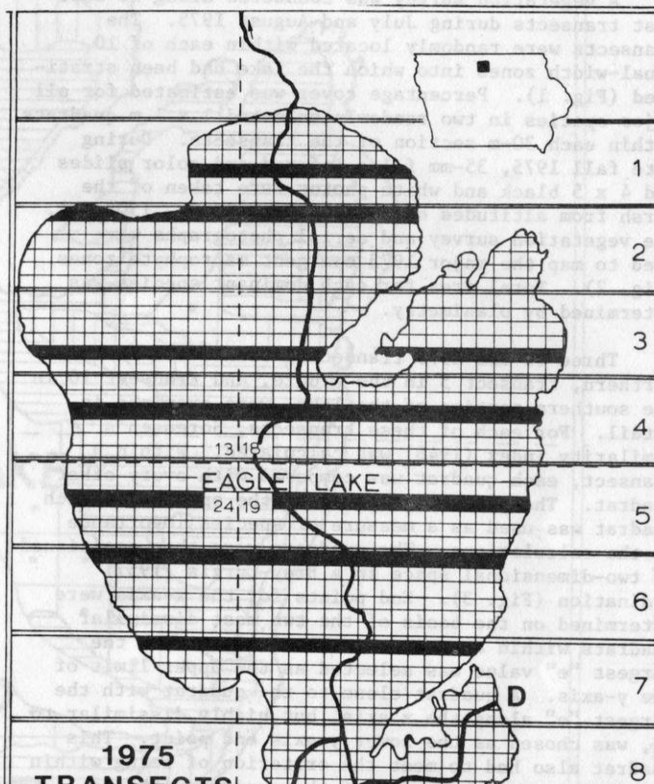


Fig. 1. Transects sampled in the 1975 vegetation survey. Major drainage ditches (A, B, C) and tile drainage (D) into the lake are shown.

(Fig. 1). Although the lake basin is natural, the water level is maintained artificially at a maximum depth of 1 - 1.5 m by a dam at the northern end. Water enters the marsh through several open drainage ditches, drainage tiles, and natural springs primarily at its southern end. The major influent is an open

---

[1] Journal Paper No. J-8806 of the Iowa Agriculture and Home Economics Experiment Station, Ames, Iowa. Project 2071.

ditch that enters the lake from the southwest and joins a main channel near the center of the southern lobe of the lake. Several other open ditches and drainage tiles also empty into this central channel, which runs the length of the lake from south to north (Fig. 1). The dam is the only known outflow.

METHODS

A vegetation survey was conducted along 10 east-west transects during July and August 1975. The transects were randomly located within each of 10 equal-width zones into which the lake had been stratified (Fig. 1). Percentage cover was estimated for all major species in two randomly selected 1 x 1 m quadrats within each 30-m section of the transects. During late fall 1975, 35-mm false-infared and color slides and 4 x 5 black and white photos were taken of the marsh from altitudes of 300 - 450 m (1000 - 1500 ft). The vegetation survey and aerial photographs were used to map the major 1975 emergent macrophyte zones (Fig. 2). Total area for each dominant species was determined by planimetry.

Three of the 1975 transects, transect 1 in the northern, transect 5 in the middle, and transect 10 in the southern portion of the lake, were examined in detail. For each of these transects, Sorensen's similarity index (1948) was calculated. Within a transect, each quadrat was compared with every other quadrat. The percentage cover of the species in each quadrat was used as a measure of species importance in the calculations. The quadrats were then positioned in two-dimensional space in a Bray-Curtis (1957) ordination (Fig. 3). End points for the x-axis were determined on the basis of the two most dissimilar quadrats within a transect. The quadrat with the largest "e" value was selected as the upper limit of the y-axis. A quadrat close to the quadrat with the largest "e" along the x axis, but highly dissimilar to it, was chosen as the lower y-axis end point. This quadrat also had to meet the criterion of being within a distance on either side of the quadrat with the largest "e", equal to 5% of the total x-axis length. Plots within each transect subsequently were grouped by dominant species.

Nomenclature follows Fassett (1957).

RESULTS AND DISCUSSION

Vegetation

Figure 2 illustrates the major vegetation zones at Eagle Lake in 1975. The largest zone is dominated by Scirpus validus (33.4% of total lake area), which occupies the deepest water in the lake and is interspersed with areas of open water (11%). Scirpus validus stands tend to be relatively open and therefore are suitable habitats for various submersed macrophytes, such as Potamogeton pectinatus and Najas flexilis, which are commonly found in these stands. Sparganium eurycarpum also occurs in some dense patches within the Scirpus validus zone, but is not dominant over any substantial area. Masses of algae (Spirogyra sp. and Rhizoclonium sp.) often are present in the open water and between clumps of Scirpus validus.

Typha spp. (T. x glauca and T. angustifolia) is probably the most ubiquitous species in the lake (28.4%). It occupies a dense band surrounding the Scirpus validus zone and often is associated with large mats of Lemna minor and Spirodela polyrhiza. In areas free of standing water except in the spring, Typha stands are less dense. Sparganium, Carex spp., and meadow species, such as Mentha arvensis and Acorus calamus, often are found scattered throughout these stands.

Carex atherodes and Carex comosa (14.8%) occur in nearly monodominant stands in large areas at the northern and southern ends of the marsh. They also occur in an almost continuous, but narrow, band along the eastern edge of the marsh. In the southern end, some Typha latifolia is found in the Carex zones. Along the eastern edge of the marsh, the narrow bands dominated by Carex also contain Typha, Sparganium, Acorus, and Polygonum natans in wetter sites, and meadow species, Mentha arvensis, Eupatorium maculatum, Iris versicolor, Polygonum lapathifolium, and Polygonum punctatum, in the drier sites near shore. Some of these species often are locally abundant.

Sparganium eurycarpum (8.8%) has a scattered distribution around the lake, but is, for the most part, confined to a region between the deep-water species, Scirpus validus and Typha, and the wet meadow species (i.e., Carex). Sparganium often occurs in large, monodominated stands, but is frequently associated with Typha, Scirpus validus, Polygonum natans, and Sium sauve.

Scirpus fluviatilis (1.9%) is dominant in only a small portion of the lake. It rarely is found in pure stands, but frequently occurs with Carex spp. and Sparganium eurycarpum along the edge of the marsh. The densest stands occupy areas adjacent to influent channels.

Phragmites australis (0.14%), Phalaris arundinacea (1.2%), and Spartina pectinata (0.36%) dominate small patches in the southern portion of the lake. Present boundaries of these species extend beyond the old standing culms, suggesting that the zones are spreading. Phragmites tends to be expanding in a circular fashion into a Typha zone (Fig. 2). Spartina occurs in the southern tip of the lake in a narrow band (Fig. 2) and is expanding laterally, forming distinct, dense clones that are associated with Carex at their edges. Phalaris arundinacea is confined primarily to the area surrounding the mouth of the major influent channel. It is encroaching upon both Carex and Typha stands as it expands along the waterway into the marsh proper.

Several other vegetation types are present at the lake, but do not cover enough area to appear on the vegetation map (Fig. 2). These include small, but widespread, patches of Sagittaria latifolia, Acorus calamus (a marsh edge species), and Impatiens biflora (a species confined to the partly shaded western shoreline).

Similar dominant vegetation zones have been found in other prairie glacial marshes in Iowa: Little Wall and Goose lakes (Weller and Spatcher 1965), Big Wall Lake (Van Dyke 1972), and Rush Lake (Weller and Fredrickson 1973). However, Sparganium and Scirpus validus tend to be much more abundant and form denser stands at Eagle Lake than elsewhere. Van Dyke (1972) found that, at Big Wall Lake, the percentage of stand biomass attributable to species other than the dominant was highest in the Sparganium-dominated stands. Few Sparganium stands were found in Goose Lake and Rush Lake (Weller and Spatcher 1965,

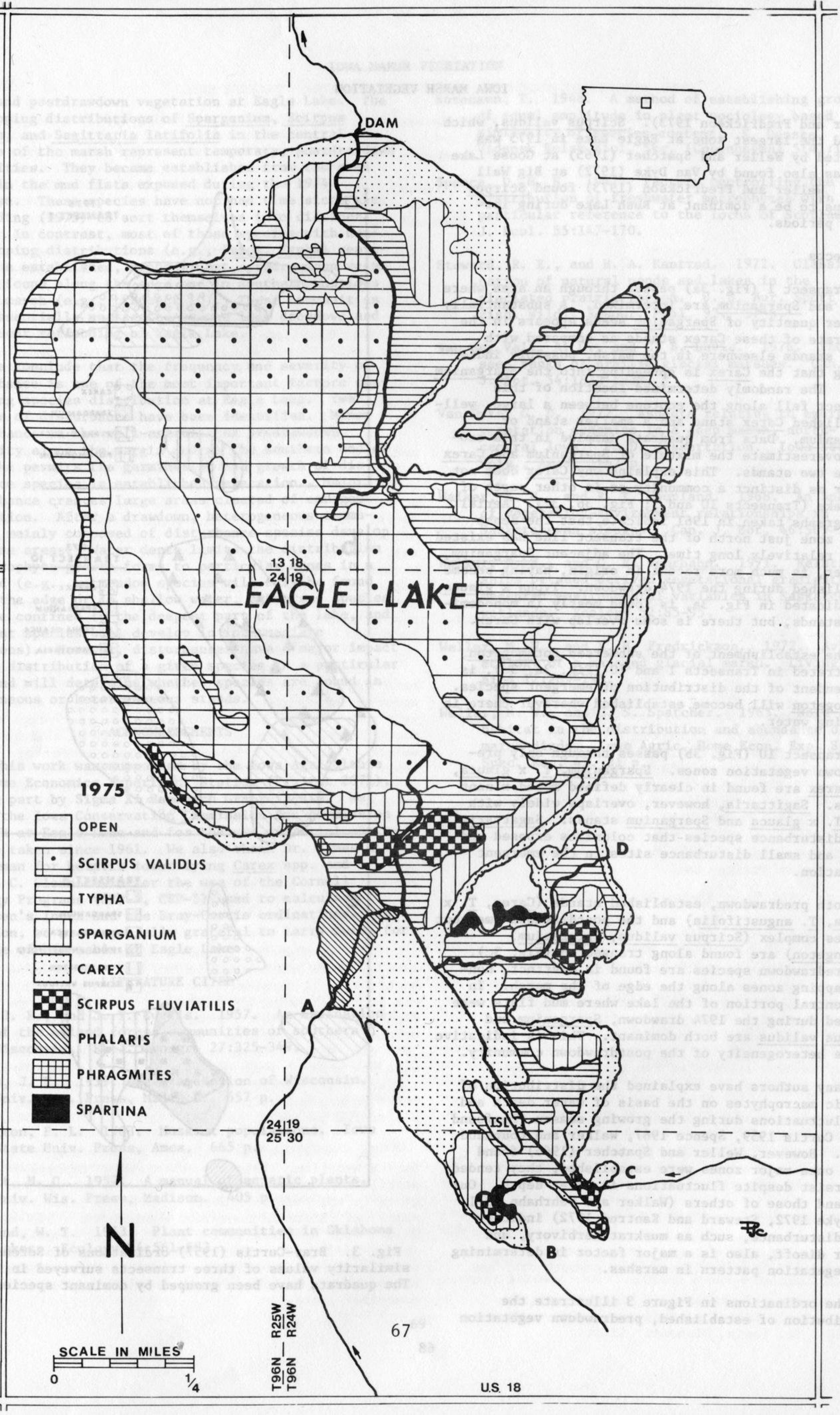


Fig. 2. Vegetation map for 1975, showing the distribution of the eight major vegetation zones.

Weller and Fredrickson 1973). *Scirpus validus*, which formed the largest zone at Eagle Lake in 1975 was reported by Weller and Spatcher (1965) at Goose Lake and was also found by Van Dyke (1972) at Big Wall Lake. Weller and Fredrickson (1973) found *Scirpus validus* to be a dominant at Rush Lake during low-water periods.

Transects

Transect 1 (Fig. 3a) passes through an area where *Carex* and *Sparganium* are intermixed. A substantially greater quantity of *Sparganium* seeds appears in the substrate of these *Carex* stands as compared with *Carex* stands elsewhere in the marsh, possibly indicating that the *Carex* is spreading into the *Sparganium* zone. The randomly determined location of this transect fell along the ecotone between a large, well-established *Carex* stand and a smaller stand of *Sparganium*. Data from quadrats sampled in this ecotone overestimate the mixture of *Sparganium* and *Carex* in the two stands. This explains why *Carex* does not appear as distinct a community as in other parts of the lake (Transects 10 and 5; Fig. 3b, 3c). Aerial photographs taken in 1961 indicate that the dense *Carex* zone just north of the transect line has existed for a relatively long time. The adjacent *Sparganium*, however, is much more recent in origin, having become established during the 1974 drawdown. *Typha* x *glauca*, as indicated in Fig. 3a, is found mostly in monodominant stands, but there is some overlap with *Carex*.

The establishment of the submersed *Potamogeton*, illustrated in Transects 1 and 10 (Fig. 3a, 3c), is independent of the distribution of emergent species. *Potamogeton* will become established wherever there is standing water.

Transect 10 (Fig. 3b) passes through only predrawdown vegetation zones. *Sparganium*, *T.* x *glauca*, and *Carex* are found in clearly defined monodominant stands. *Sagittaria*, however, overlaps widely with both *T.* x *glauca* and *Sparganium* stands. *Sagattaria* is a disturbance species that colonizes exposed mud flats and small disturbance sites in the emergent vegetation.

Both predrawdown, established stands (*Carex*, *T.* x *glauca*, *T. angustifolia*) and the postdrawdown emergent species complex (*Scirpus validus*, *Spraganium*, *Potamogeton*) are found along transect 5 (Fig. 3c). The predrawdown species are found in distinct, non-overlapping zones along the edge of the marsh. In the central portion of the lake where mud flats were exposed during the 1974 drawdown, *Sparganium* and *Scirpus validus* are both dominant. This is indicative of the heterogeneity of the postdrawdown community.

Many authors have explained the distribution of aquatic macrophytes on the basis of water depth and its fluctuations during the growing season (Penfound 1953, Curtis 1959, Spence 1967, Walker and Coupland 1968). However, Weller and Spatcher (1965) found that, once major zones were established, they tended to persist despite fluctuations in water depth. Our data and those of others (Walker and Wehrhahn 1971, Van Dyke 1972, Steward and Kantrud 1972) indicate that disturbance, such as muskrat herbivory, and winter dieoff, also is a major factor in determining the vegetation pattern in marshes.

The ordinations in Figure 3 illustrate the distribution of established, predrawdown vegetation

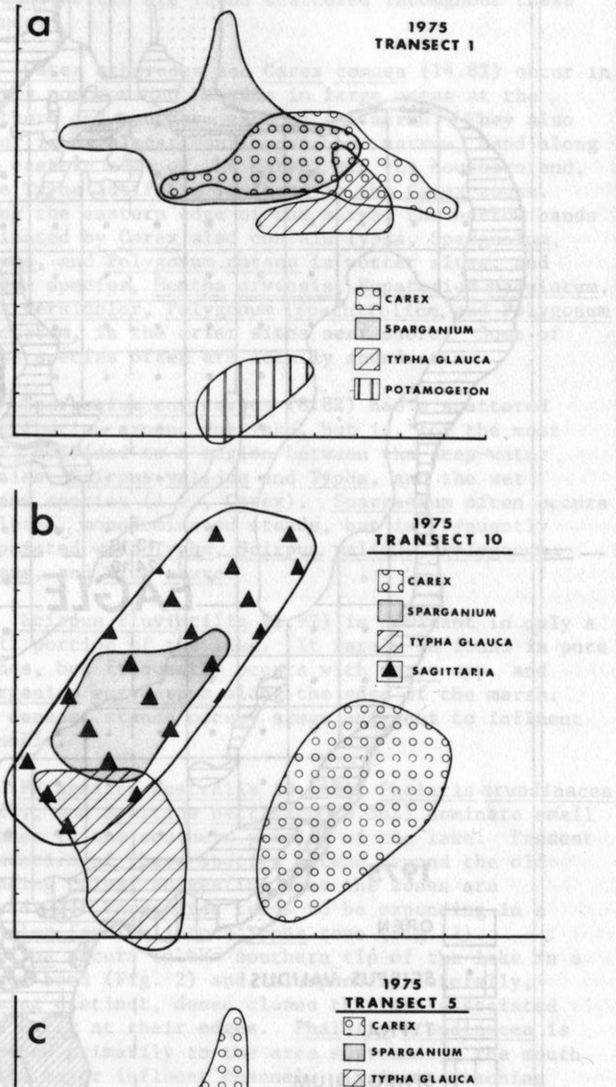


Fig. 3. Bray-Curtis (1957) ordinations of Sorensen's similarity values of three transects surveyed in 1975. The quadrats have been grouped by dominant species.

zones and postdrawdown vegetation at Eagle Lake. The overlapping distributions of Sparganium, Scirpus validus, and Sagittaria latifolia in the central portion of the marsh represent temporary, postdrawdown communities. They became established from the seed banks in the mud flats exposed during the 1974 drawdown. These species have not had time since the reflooding (1975) to sort themselves into distinct zones. In contrast, most of those species with non-overlapping distributions (e.g., Carex, Typha) represent the established, monodominant, predrawdown vegetation found along the edge and in southern portions of the marsh (e.g., transect 10). These communities were essentially unaffected by the 1974 drawdown and subsequent reflooding of Eagle Lake.

We conclude that the frequency and severity of disturbance is one of the most important factors controlling species distribution at Eagle Lake. Two results of disturbance have been identified. Minor disturbance in the well-established predrawdown community along the margin and at the southern end of the lake permits the germination and growth of disturbance species in established vegetation. Major disturbance creates large areas cleared of emergent vegetation. After a drawdown, heterogeneous communities mainly composed of disturbance species develop in these areas. Water depth limits the distribution of macrophyte growth forms to particular zones in a wetland (e.g., wetmeadow species will only be found along the edge or in shallow water, submersed species will be confined to the deepest part of the lake, and emergent species will develop in intermediate positions). However, disturbances have a major impact on the distribution of a given species in a particular zone and will determine whether species are found in homogeneous or heterogeneous stands.

ACKNOWLEDGMENTS

This work was supported by the Iowa Agriculture and Home Economics Experiment Station (Project 2071), and in part by Sigma Xi Research Grant-in-Aid. We thank the Iowa Conservation Commission for permission to work at Eagle Lake and for the use of aerial photographs taken since 1961. We also thank Dr. James H. Zimmerman for help in identifying Carex spp. and Dr. D. C. Glenn-Lewin for the use of the Cornell Ecology Programs (CEP-4, CEP-5) used to calculate Sorensen's Index and the Bray-Curtis ordinations. In addition, we are especially grateful to Larry Ewers for the use of his cabin at Eagle Lake.

LITERATURE CITED

Bray, J. R., and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27:325-349.

Curtis, J. T. 1959. The vegetation of Wisconsin. Univ. Wis. Press, Madison. 657 p.

Errington, P. L. 1963. Muskrat populations. Iowa State Univ. Press, Ames. 665 p.

Fassett, N. C. 1957. A manual of aquatic plants. Univ. Wis. Press, Madison. 405 p.

Penfound, W. T. 1953. Plant communities in Oklahoma lakes. Ecology 34:561-583.

Sorensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. K. Danske Vidensk Selsk Biol. Skr. (Copenhagen) 5(4):1-34.

Spence, D. H. N. 1967. Factors controlling the distribution of freshwater macrophytes with particular reference to the lochs of Scotland. J. Ecol. 55:147-170.

Steward, R. E., and H. A. Kantrud. 1972. Classification of natural ponds and lakes in the glaciated prairie region. U. S. Bur. Sport Fish. Wildl. Resour. Publ. 92. 57 p.

van der Valk, A. G., and C. B. Davis. 1976. The seed banks of prairie glacial marshes. Can. J. Bot. 54:1832-1838.

Van Dyke, G. D. 1972. Aspects relating to emergent vegetation dynamics in a deep marsh, north-central Iowa. Ph.D. dissertation. Iowa State Univ., Ames. 162 p.

Walker, B. H., and R. T. Coupland. 1968. An analysis of vegetation-environment relationships in Saskatchewan sloughs. Can. J. Bot. 46:509-522.

Walker, B. H., and C. E. Wehrhahn. 1971. Relationships between derived vegetational gradients and measured environmental variables in Saskatchewan wetlands. Ecology 52:85-95.

Weller, M. W., and L. H. Fredrickson. 1972. Avian ecology of a managed glacial marsh. Living Bird 12:269-291.

Weller, M. W., and C. S. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa Agric. Home Econ. Exp. Stn. Spec. Rep. 43. 31 p.

TOTAL AND LIVING MICROBIAL BIOMASS FROM TALLGRASS PRAIRIE SOIL

R. P. Herman[1]
and
C. L. Kucera

Division of Biological Sciences
University of Missouri
Columbia, Missouri 65201

ABSTRACT

Total soil microbial biomass from control and annually-burned plots is calculated from bacterial cell counts obtained by direct observation and from mycelial lengths estimated by filtration of soil samples. Living bacterial biomass is determined by plate counts while live fungal tissue is estimated by autoradiography of ^{14}C incorporated into mycelium. Estimates of nonbacterial (primarily fungal) biomass are made using the firefly luminescence assay for soil ATP. Differences in control and annually-burned areas are discussed. Microbial tissue as a source of soil organic matter differences is considered.

INTRODUCTION

The Tucker Prairie Research Station has been extensively studied for almost twenty years. One of the major emphases of these studies has been the fate of photosynthetically-fixed carbon as it passes through the various compartments of the tallgrass prairie ecosystem. The soil compartment of Tucker Prairie has received considerable attention. The initial work on the area included a study of the changes of the physical properties of the soil in response to vegetation management (Kucera 1958). Soil respiration has been monitored (Kucera and Kirkham 1971, Herman and Kucera 1975). This respiration has been apportioned between roots and heterotrophs (Kucera and Kirkham 1971, Herman 1977). The size and turnover characteristics of the root compartment have been determined (Kucera and Dahlman 1968, Dahlman and Kucera 1969). This study attempts to clarify the size and characteristics of the microbial contribution to the organic matter in Tucker Prairie soil.

METHODS

Study Area

Tucker Prairie Research Station is a 50 ha plot of native prairie located in Callaway County (T 48N, R 10W, Sec. 12, SW 1/4), 27 kilometers east of Columbia, Missouri. Vegetation is dominated by *Andropogon scoparius* (little bluestem), *A. gerardii* (big bluestem), *Sporobolus heterolepis* (prairie drop seed), and several species of the genera *Solidago*, *Aster* and *Helianthus*.

Two treatment areas were studied. The control and annually-burned plots were 30-by-60 meter areas established in 1958. The control plot has been free of disturbance since that time, while the burned area has been burned each year in late March or early April.

Bacterial Numbers

Soil samples were obtained during May 1976, using a tube sampler 2.5 cm in diameter to a depth of 5 cm. The sampler was alcohol flame sterilized between samples. Twenty-five cores per area were collected. The samples were bagged in plastic bags and returned to the laboratory for immediate processing.

Soil was suspended in a Virtis homogenizer at high speed for two minutes total blending time. Blending was carried out in time periods thirty seconds long with two minutes between homogenizations to avoid overheating.

The medium for plate counting was soil extract modified with the addition of 0.5% bacto-peptone and 0.5% glucose. One liter of tap water and 100 g dry weight soil were autoclaved for 15 min and filtered to obtain the soil extract. Two ml of 0.1% crystal violet was added as an antifungal agent. The pH was adjusted to give a final pH of seven. This amended soil extract medium was chosen because it yielded maximum counts in preliminary studies. Dilution series were made and plated. Plates were counted that had from 20 to 100 colonies. The results of these counts were converted to yield the number of live bacterial cells per gram oven dry weight of soil.

Direct counts were estimated by counting diluted soil suspensions in Petroff-Hauser counting cells under phase contrast optics. Ten fields per slide were counted and three slides per core were prepared. Bacterial cells were calculated to have an average weight of 1.1×10^{-13} g/cell based on an average length of 1 micron with an average width of 0.4 micron and assuming a specific gravity of 1.1 with a dry weight equal to 20% of fresh weight. The average bulk density of this soil to the depth of 5 cm is 1.0 (Kucera 1958). The dry weight of cells per meter square to a depth of 5 cm can be calculated as: number of cells/g soil $\times$ 1.1×10^{-13} g/cell $\times$ 5×10^4 cm^3 soil $\times$ 1 g/cm^3 soil.

Fungal Biomass

Soil samples for the estimation of fungal biomass were obtained and handled in the same manner as bacterial soil samples. The length of hyphae in soil was estimated using the millipore filter technique of Hanssen et al (1974). Lengths were converted to volumes using an average measured diameter of 2.2×10^{-4} cm. These volumes were then converted to biomass per gram of soil assuming a specific gravity of 1.1 and a dry weight equivalent to 20%. Biomass per meter square was calculated using the same assumptions as for the bacterial samples.

Live mycelium was estimated by labeling the living mycelium. This was accomplished by applying a sterile hot water extract of dried ^{14}C-labeled prairie grass to the soil for twenty-four hours prior to sampling. Extracts contained approximately 5000 dpm/ml. Slides were prepared as for total hyphal lengths and then dipped in photographic emulsion. Autoradiographs were developed and lengths of labeled hyphae determined. These values were converted to biomass as described above.

---

[1]Present address: Department of Microbiology, St. Louis University School of Medicine, 1402 So. Grand Boulevard., St. Louis, Missouri 53104

Soil ATP

Soil ATP was determined using the firefly luminescence assay. A slurry of soil was sieved to remove root tissue. The equivalent of one gram dry weight of soil was extracted with five ml of 0.05M Tris-HCl buffer (pH 7.6) containing 6 mM MgCl. The sample tubes were vortexed for two minutes. Five ml of N-propanol were added to the tubes which were again vortexed for two minutes. Ten ml of octanol was added and the tubes were inverted thirty times by hand. The samples were centrifuged at 1,000 x g for fifteen minutes. The organic phase was removed by suction and the aqueous phase was retained. Firefly lantern extract was obtained from Sigma Chemical Co., and prepared according to their directions. One ml of the aqueous phase was reacted with 0.3 ml of firefly extract in tubes in the well of a photomultiplier tube. The output was amplified and recorded. Peak heights were measured and ATP content calculated from standard curves obtained for each batch of firefly extract. Known quantities of living fungal (8.0 x 10^{-5} cm^3) and bacterial (1.6 x 10^8 cells) tissues were added to sterilized soil to determine their ATP content.

Soil Organic Matter

Soil organic matter was determined using an oxygen tube furnace.

RESULTS

Figure 1 presents the number of bacterial cells per gram of soil. The control area had a total of 4.2 ($\pm$ 0.63) x 10^9 cells per gram of soil with 1.6 ($\pm$ 0.28) x 10^8 cells per gram live. This represents 3.8% live cells. The burned area had a total of 5.2 ($\pm$ 0.81) x 10^9 cells per gram of soil with 2.3 ($\pm$ 0.31) x 10^8 live cells per gram. The burned area had 4.4% live cells. The total number of bacterial cells did not vary significantly between the areas, however, the burned area had significantly more live cells ($p < .05$).

Hyphal lengths per gram of soil are presented in Figure 2. The control area had 6.54 ($\pm$ 1.02) x 10^4 cm of mycelium with 0.21 ($\pm$ 0.03) x 10^4 cm live fungal hyphae. The living mycelium represented 3.2% of the total. The burned area had 7.01 ($\pm$ 0.98) x 10^4 cm of mycelium with 0.26 ($\pm$ 0.03) x 10^4 cm of live mycelium. The live hyphae represented 3.7% of the total. Neither the total nor living hyphal lengths were significantly different between the two areas.

Total biomass data are presented in Figure 3. The control area has 23.2 grams of bacteria per meter square to a depth of five cm with 0.9 g live, and 27.4 g of mycelium with 0.9 g live for a total of 50.6 g of which 1.8 g or 3.6% was live. The burned area had 28.7 grams per meter square bacterial cells with 1.3 grams per meter square live and 29.3 grams per meter square of fungal mycelium with 1.1 grams per meter square live hyphae, for a total of 58.0 grams per meter square with 2.4 grams per meter square live which represented 4.1%.

Mean soil ATP content for both treatment areas was 1.0 μg ATP per gram of soil. Sample to sample variability was great while values for duplicate determinations from one sample were quite consistent. Standardizing determinations showed that 1.6 x 10^8 bacterial cells yielded 0.26 μg of ATP while 8.0 x

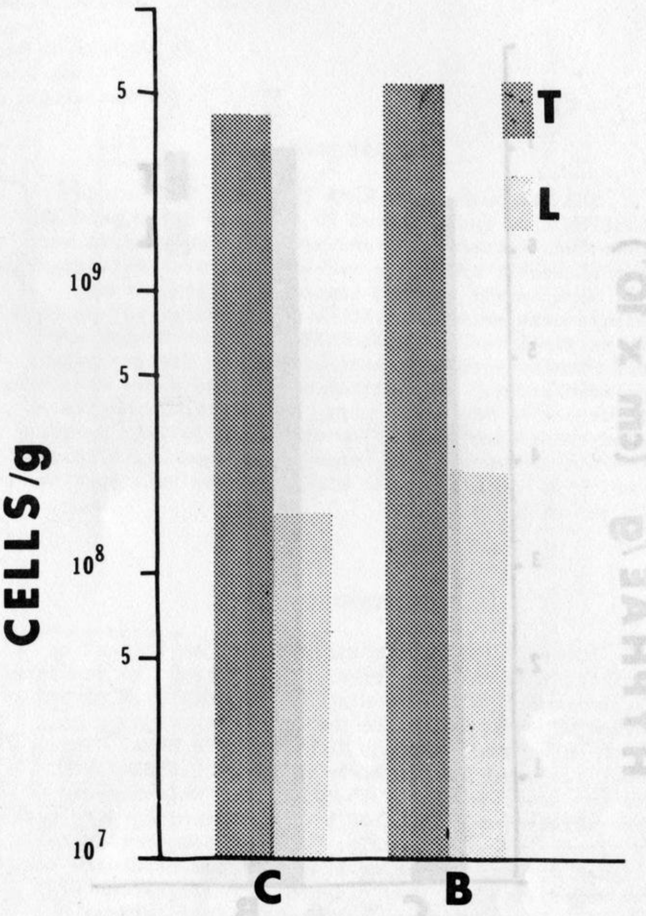


Fig. 1. Bacterial cells per gram oven dry weight of soil divided into total (T) and living (L) compartments for the control (C) and burned (B) treatment areas. Note the logarithmic scale.

10^{-5} cm^3 of mycelium yielded 0.28 μg of ATP.

Soil organic matter for the control area was 8.1% while the burned area contained 8.4% organic matter in the top five cm of soil.

DISCUSSION

The values of 50.6 and 58.0 grams microbial biomass per square m x 5 cm are comparable to the average of 70 grams per meter square x 10 cm recorded for grassland soils by Clark and Paul (1970). The most unusual aspect of the values obtained in the present study was the relative proportion of bacterial and fungal biomass. This study showed approximately equal mass of bacteria and fungi. Clark and Paul (1970) reported the more usual ratio for prairie soils of about twice as much fungal biomass as bacterial biomass. It is possible that the difference in ratios could in part be explained by differences in depths of the profiles used.

While the differences in bacterial and fungal biomass between the treatment areas were not usually

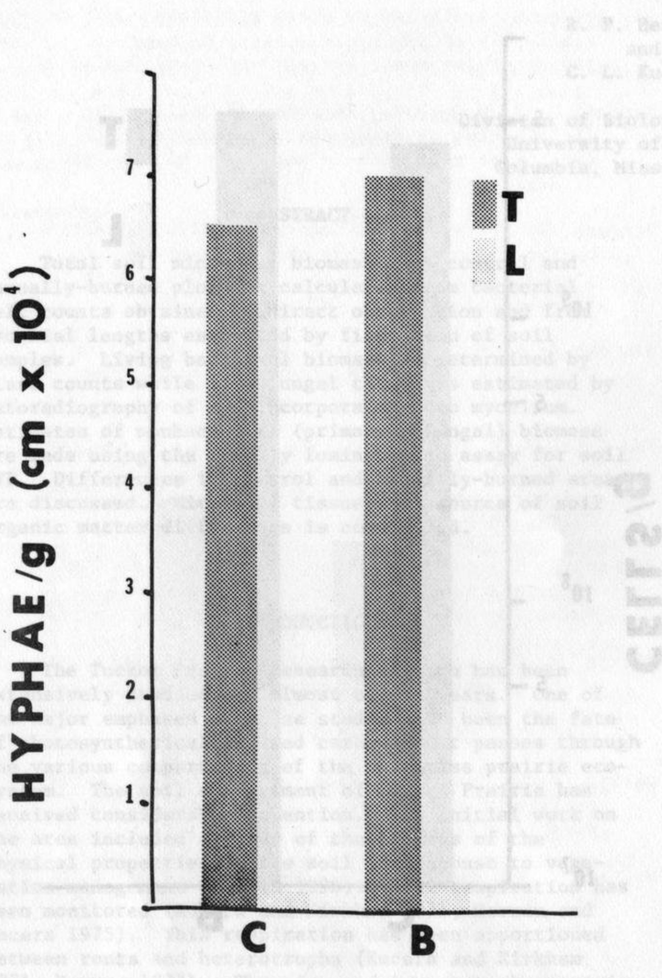


Fig. 2. Lengths of fungal hyphae per gram oven dry weight of soil divided into total (T) and living (L) compartments for the control (C) and burned (B) treatment areas.

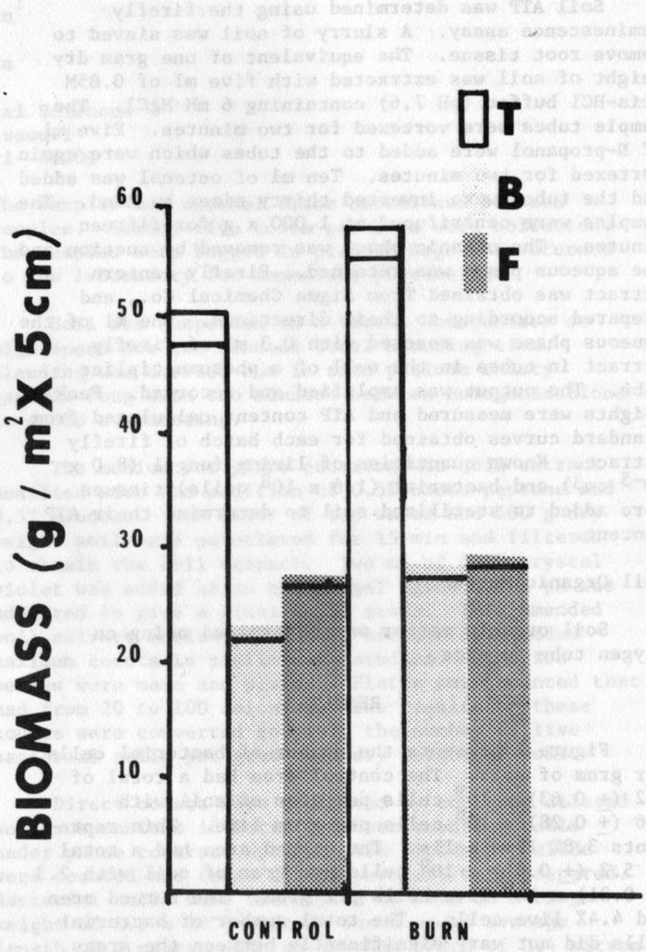


Fig. 3. Biomass of microbial tissue per m^2 to a depth of five cm from the control and burned areas expressed as total (T) bacterial (B) and fungal (F) biomass. The area above the solid line represents the portion of the compartment composed of living tissue.

statistically significant, the burned area routinely had the higher values. While not statistically significant, this difference may represent a trend. If so, it would be consistent with the observations found for higher plant biomass (Kucera and Koelling 1964). The higher proportion of live cells in the burned area might indicate a higher turnover of microbial tissue under these treatment conditions. The values obtained for the mass of recognizable microbial tissue represent only a small portion of the total organic matter in the top five cm of Tucker Prairie soil. The total organic matter in the top five cm of the control and burned areas was 4050 and 4200 grams per m^2 respectively. The identifiable microbial tissue from the control area represented 1.3% of the total organic matter while microbial tissue from the burned area accounted for 1.4% of the total. While this was a seemingly small portion of the total organic matter, it represented only that tissue of microbial origin which was sufficiently intact to be identified as bacterial cells or fungal hyphae. Microbial tissue in various states of decay probably represented a considerably larger portion of the total organic matter than the identifiable microbial tissue. Jansson (1960) and Shields et al (1973) pointed out the stability of added ^{14}C label once it had been incorporated into microbial tissue. Shields et al (1974) demonstrated that the bulk of added ^{14}C label was found in stabilized material not identifiable as microbial tissue.

The soil ATP assay was remarkably consistent in determining the quantity of ATP in a given soil sample. However, the variation among samples even from the same treatment area was so large as to make its usefulness in soil biology questionable. The intended use of the ATP assay was to determine non-bacterial living biomass. Living bacteria in the control area (1.6×10^8 cells/g) accounted for 0.26 µg of ATP, leaving 0.74 µg to be accounted for by other soil organisms. Living fungi as estimated by autoradiography (7.98×10^{-5} cm^3/g soil) accounted for only 0.28 µg ATP. This left 0.46 µg or almost half the ATP recovered to be accounted for by other soil organisms or root contamination. When filters were prepared for examining hyphal lengths, only a few roots were found in the fields. The only other organisms observed were a few diatoms. It is possible, however, that this ATP could be accounted for by living organisms such as nematodes which would unlikely be found on the filters. Since the consistency of the autoradiographic technique was much greater than the ATP assay and since it was much more specific for fungi, these results represent a much more accurate accounting of live fungal biomass.

LITERATURE CITED

Clark, F. E., and E. A. Paul. 1970. The microflora of grasslands. In: N. C. Brady, ed. Advances in Agronomy 22:375-435.

Dahlman, R. C., and C. L. Kucera. 1969. Root productivity and turnover in native prairie. Ecology 46:87-89.

Hanssen, J. F., T. F. Thingstad, and J. Goksøyr. 1974. Evaluation of hyphal lengths and fungal biomass in soil by a membrane filter technique. Oikos 25:102-107.

Herman, R. P. 1977. Root contribution to "Total Soil Respiration". Am. Midl. Nat. (in press)

Herman, R. P., and C. L. Kucera. 1975. Vegetation management and microbial function in a tallgrass prairie. Iowa St. J. Res. 50:255-260.

Jansson, S. L. 1960. On the establishment and use of tagged microbial tissue in soil organic matter research. 7th International Congress Soil Science Proceedings, Madison. 2:635-642.

Kucera, C. L. 1958. Some changes in the soil environment of a grazed-prairie community in central Missouri. Ecology 39:538-540.

Kucera, C. L., and R. Dahlman. 1968. Root-rhizome relations in fire-treated stands of big blue stem Andropogon gerardi Vitman. Am. Midl. Nat. 80:268-271.

Kucera, C. L., and D. R. Kirkham. 1971. Soil respiration studies in tallgrass prairie in Missouri. Ecology 52:912-915.

Kucera, C. L., and M. Koelling. 1964. The influence of fire on composition of central Missouri prairie. Am. Midl. Nat. 72:142-147.

Shields, J. A., E. A. Paul, W. E. Lowe, and D. Parkinson. 1973. Turnover of microbial tissue in soil under field conditions. Soil Biol. Biochem. 5:753-764.

Shields, J. A., E. A. Paul, and W. E. Lowe. 1974. Factors influencing the stability of labeled microbial materials in soil. Soil Biol. Biochem. 6:31-37.

THE USE OF BETA ATTENUATION TO MEASURE PRODUCTIVITY, FOLIATE HEIGHT DIVERSITY, AND VEGETATIONAL HETEROGENEITY IN TALLGRASS PRAIRIE[1]

Michael P. Johnson, Lauri Oksanen, and Chris Finney

Konza Prairie Research Natural Area
Kansas State University
Manhattan, Kansas 66506

ABSTRACT

The attenuation of beta radiation by prairie standing crop was measured in quadrats which were also harvested. Attenuation and harvest measurements were made at weekly intervals and at five sites differing in soil type and/or burning treatment. Attenuation measurements were made within each quadrat across both the vertical and horizontal dimensions. Living and dead biomass were separated at harvest for dry weight determinations. Attenuation measurements are excellent predictors of standing crop. The vertical profile of measurements may be used to determine foliage height diversity. Patterns of temporal and spatial heterogeneity in vegetation are also shown by this particular set of measurements.

INTRODUCTION

Mitchell (1972) demonstrated for shortgrass prairies that standing plant biomass could be predicted by the amount of beta radiation absorbed by a given volume of vegetation. He used a sheet of paper on which strontium^{90} was applied in liquid form. This sheet was taped on the backside of a cardboard box. The box was placed over the grass and measurements of the radiation not absorbed by the vegetation were made by placing a Geiger-Mueller tube in three horizontally aligned notches on the frontside of the cardboard box. The vegetation was then clipped for calibration with the beta-attenuation measurements. Correlations between dry-weights and beta-attenuation measurements were as high as .97 depending on the regression model used. Can this technique be applied to the more complex tallgrass prairies?

The application of this technique to tallgrass prairies requires a basic change in sampling strategy from two to three dimensions. Beta-attenuation measurements at only one height would clearly not give information on seasonal changes in standing biomass. Vertical as well as horizontal sampling would require more time, but would also give additional information on the spatial distribution of biomass. MacArthur and MacArthur (1961), using a primitive method of measuring the vertical distribution of biomass in forests, have correlated foliage height diversity with bird species diversity. Similar results have been observed in grasslands by Cody (1968) and others. We will now relate the use of beta-attenuation as a method of estimating standing biomass (which as sequential measurements may be used to estimate productivity) and as a method of describing the horizontal and vertical distribution of biomass.

METHODS

Vegetation sampling. Five sites on the Konza Prairie Research Natural Area were sampled using beta-attenuation. Concurrent clipping with dry weight determinations were done on four sites; Tully soil annually burned, Tully soil unburned, Florence soil annually burned, and Florence soil unburned (Fig. 1). The Florence soil is a shallow upland soil and Tully soil represents the deeper lowland soil types. Weekly sampling was done on the burned sites during June, July and part of August, 1975. At least ten 20 x 50 cm. quadrats were clipped at each weekly sampling. Beta-attenuation measurements were made within the same quadrats prior to clipping.

The vegetation was clipped down to a height of about 1 cm and only standing material was harvested. The material was separated into living and dead categories in the field. The samples were placed in paper bags, dried for four days at 60°C, and weighed. The clipped vegetation was not stratified as were the beta-attenuation measurements.

Beta-attenuation measurements. The beta-attenuation measurements were made using a local shop-made frame designed by L. C. Hulbert and mounted with a Ludlum Model 2000 Scaler, a Geiger-Mueller tube and a 100 microcurie Strontium^{90} source capsule (Fig. 2). The capsule is small enough to be considered a point source. The source and the GM tube move independently on the frame and are locked by pins spaced every five centimeters along the frame. The operator stands behind the source which is housed in a lead shield with a door open only while measurements are being made. These features are provided for the safety of the operator. The entire unit cost is about $1200.

The appropriate strength of the source and other properties of the sampler were determined as a class project in a nuclear engineering course. Because of the magnitude of vegetational heterogeneity a test sampling method using a single measurement/quadrat/height proved unsatisfactory. This problem was much more serious in our study than in Mitchell's (1972) because of our use of a point source. Four measurements of 0.2 minutes each spaced across the 20 cm edge of the quadrats were determined to be sufficient. Measurements were initially made at five centimeter intervals to the height of the vegetation. As the season progressed and plant height increased the intervals were increased to ten centimeters.

Surface moisture has an important effect on beta-attenuation. On two days with heavy dew we sampled throughout the day at a single point. The counts per minute leveled off at the time when water droplets were no longer visible on plant surfaces. All measurements were made when that condition was met.

RESULTS AND CONCLUSIONS

A summary of the seasonal changes in standing biomass is given in Fig. 3. These are the data for which the technique is designed, and we include them because they are in themselves important. However, the real intent of this study was to see how well we could predict the dry weight values using the beta-attenuation method. For the dry weights of each quadrat there is an associated set of beta attenuation values representing the mean value at each height.

[1]Contribution # 1305-A, Division of Biology, Kansas State Agricultural Experiment Station.

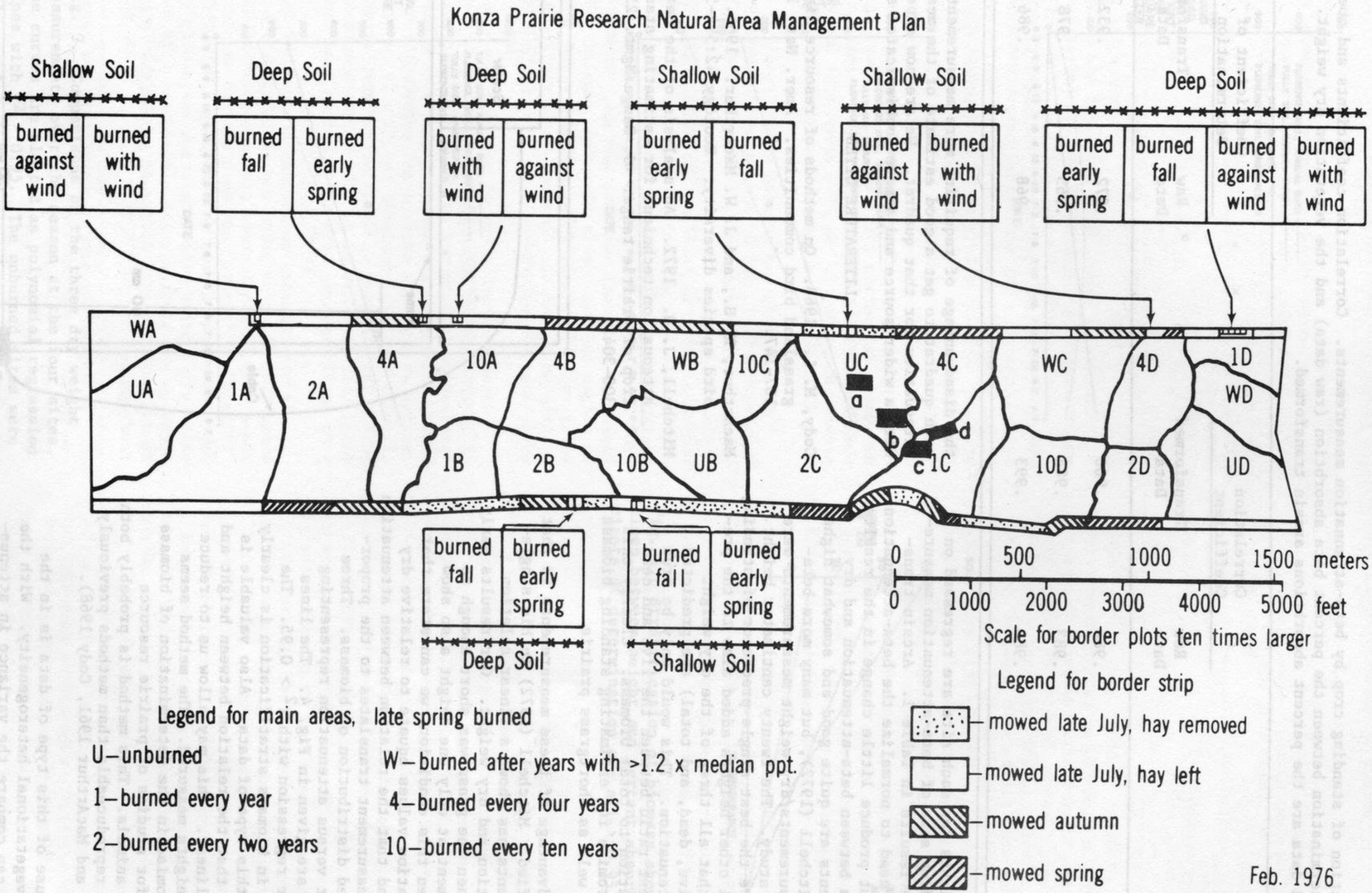


Fig. 1. Location of sampling sites on Konza Prairie Research Natural Area. Tully soil-unburned (b), Tully soil-annually burned (c), Florence soil-unburned (a), and Florence soil-burned (d).

Table 1. Prediction of standing crop by beta-attenuation measurements. Correlation coefficients and coefficients of determination between the percent beta absorbtion (raw data) and the vegetation dry weight. Transformed data are the percent absorbtions arcsin transformed.

Dependent Variable	Correlation Coefficient		Coefficient of Determination	
	Raw Data	Transformed Data	Raw Data	Transformed Data
Standing Live	.986	.966	.972	.932
Standing Dead	.983	.988	.965	.978
Standing Total	.984	.993	.968	.986

The mean dry weights for each site are regressed on their corresponding sets of beta-attenuation measurements giving the results in Table 1. Arcsin transformations were used to normalize the beta-attenuation measurements, but produce little change in the results. The correlations between beta-attenuation and dry weight measurements are quite good and somewhat higher than those of Mitchell (1972), but many more beta-attenuation measurements/dry weight measurements were included in our study. The twenty centimeter height measurements were the best single predictor of standing biomass, but all other heights added also to the prediction. Note that all three of the dry weight measurements (live, dead, and total) are predicted well by beta-attenuation. This would only be true given a consistent ratio between the live and dead material in relation to total biomass. Clearly this technique has promise for estimating standing biomass in tallgrass as well as shortgrass prairie.

A second advantage of these measurements is that they are stratified. Mitchell (1972) in his single-height measurements has shown a linear relation between attenuation and dry weight. Our results early in the season when the grass was short enough to require measurement at only one height also show linearity. Given this condition, we can state that relative attenuation values equate to relative dry weight values and that the relation between attenuation and height of measurement translates to the proportional stratified distribution of biomass. Three curves of height versus attenuation representing different dates are given in Fig. 4. The lines represent linear regression with $r^2 > 0.95$. The seasonal change in biomass stratification is clearly represented by this type of data. Also valuable is the observation that the relation between height and attenuation is linear. This may allow us to reduce the number of heights measured. The method seems also to hold promise in the determination of biomass stratification for studies of prairie resource partitioning by animals. This method is probably both faster and more reproduceable than methods previously used (MacArthur and MacArthur 1961, Cody 1968).

The third use of this type of data is in the examination of vegetational heterogeneity. With the point source we can compare the variance in attenuation measurements within quadrats, between quadrats, and between treatments. The major source of variation in measurements is within quadrats, or microhabitat variation. One sees very different vertical profiles for grasses as compared to forbs. While this observation is interesting, the use of the point source has the disadvantage of requiring more measurements in each quadrat to get a good estimate of the mean attenuation for that quadrat. We are now experimenting with a wider source and a more sophisticated sampler.

LITERATURE CITED

Cody, M. L. 1968. On methods of resource division in grassland bird communities. Amer. Nat. 102: 107-147.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594-598.

Mitchell, J. E. 1972. An analysis of the beta-attenuation technique for estimating standing crop of prairie range. J. Range Mgmt. 25: 300-304.

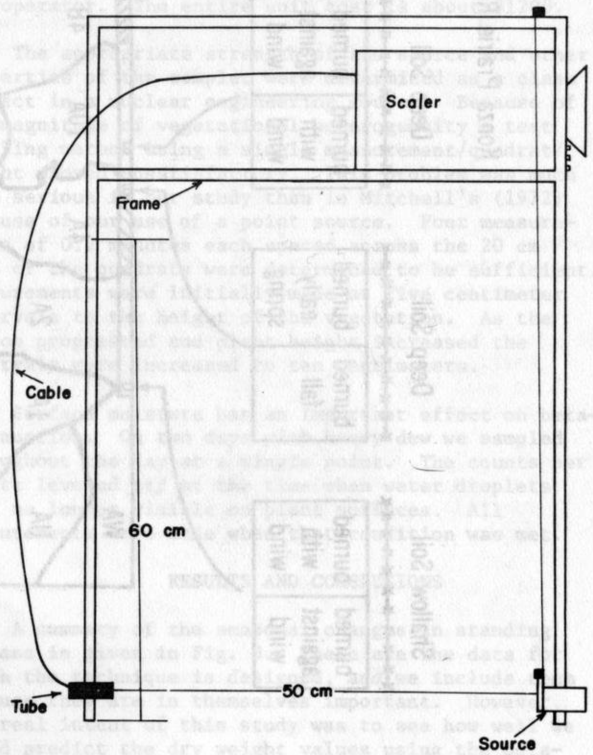


Fig. 2. Diagram of the Hulbert beta-attenuation vegetation sampler.

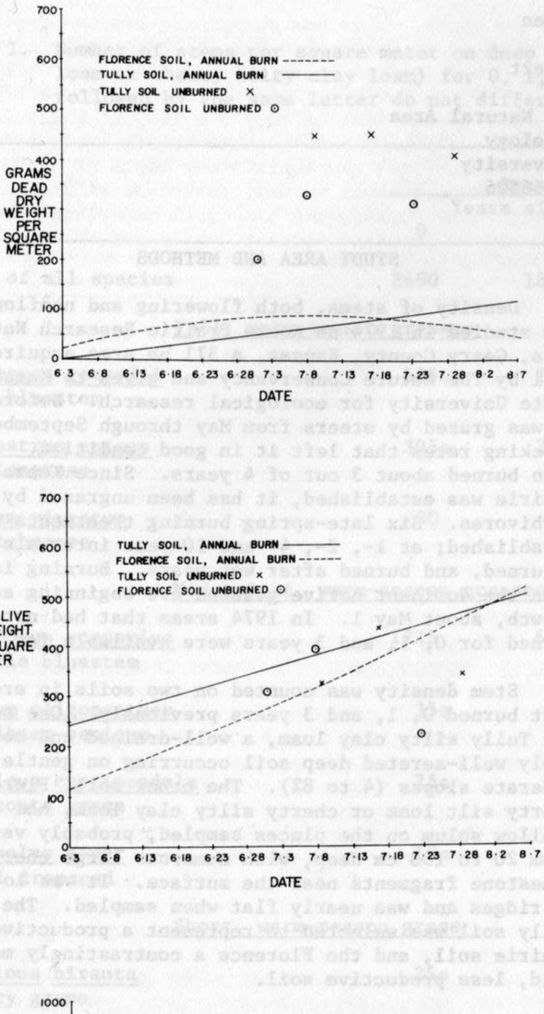


Fig. 3. Comparisons of the three dry weight measurements over the season at the four sites. The curves are plotted as polynomial regression lines with $r^2 > 0.95$. The unburned sites were only sampled three times and are represented by points.

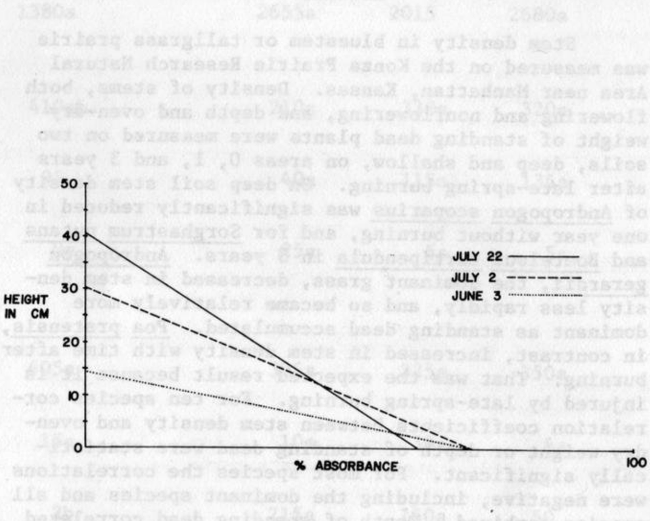


Fig. 4. Stratification of biomass shown as regression lines between height and percent absorbance. Coefficients of determination are all > 0.95.

EFFECT OF STANDING DEAD PLANTS ON STEM DENSITY IN BLUESTEM PRAIRIE

Dee Ann Dokken
and
Lloyd C. Hulbert

Konza Prairie Research Natural Area
Division of Biology
Kansas State University
Manhattan, KS 66506

ABSTRACT

Stem density in bluestem or tallgrass prairie was measured on the Konza Prairie Research Natural Area near Manhattan, Kansas. Density of stems, both flowering and nonflowering, and depth and oven-dry weight of standing dead plants were measured on two soils, deep and shallow, on areas 0, 1, and 3 years after late-spring burning. On deep soil stem density of Andropogon scoparius was significantly reduced in one year without burning, and for Sorghastrum nutans and Bouteloua curtipendula in 3 years. Andropogon gerardii, the dominant grass, decreased in stem density less rapidly, and so became relatively more dominant as standing dead accumulated. Poa pratensis, in contrast, increased in stem density with time after burning. That was the expected result because it is injured by late-spring burning. For ten species correlation coefficients between stem density and oven-dry weight or depth of standing dead were statistically significant. For most species the correlations were negative, including the dominant species and all species combined. Depth of standing dead correlated with stem density about as well as did weight of standing dead, which could be of importance because depth can be obtained much more easily than weight.

INTRODUCTION

Several studies have shown that bluestem or tallgrass prairie produces more forage after being burned than when unburned (e.g., Kucera and Ehrenreich 1962, Old 1969). Hulbert (1969) reported the same increase from clipping removal as from burning removal of old growth. Clearly it is beneficial for prairie vegetation to remove the deep, old, standing dead plants (hereafter called just "standing dead") in undisturbed bluestem prairie. Old (1969) has elucidated some of the causes of this response to burning, but little has been done to elucidate the effect of burning on stem density and stem weight. Hulbert (1969) found that removing standing dead about 40 cm deep in long-undisturbed bluestem prairie on deep soil distinctly increased stem density. The stem density in May increased less than yield due to burning, indicating that stems were both denser and larger after burning. However, stem density declined markedly by July 1 in the undisturbed control, so that by then the increase in yield was less than the increase in stem density due to burning. Weaver and Rowland (1952) had obtained similar results in a 15-year undisturbed prairie in Nebraska on deep soil. They found that stem density was about 39 per cent lower in undisturbed prairie than where standing dead had been removed.

This study was designed to further our understanding of the effect of fire on bluestem prairie by assessing the effect of time after burning on stem density on both deep and shallow soils in ungrazed bluestem prairie.

STUDY AREA AND METHODS

Density of stems, both flowering and nonflowering, was studied in 1974 on Konza Prairie Research Natural Area, Geary County, Kansas, a 371 ha area acquired in 1971 by The Nature Conservancy and given to Kansas State University for ecological research. Before 1972 it was grazed by steers from May through September at stocking rates that left it in good condition. It had been burned about 3 out of 4 years. Since Konza Prairie was established, it has been ungrazed by large herbivores. Six late-spring burning treatments were established; at 1-, 2-, 4- and 10-year intervals, unburned, and burned after wet years. Burning is done when the dominant native grasses are beginning active growth, about May 1. In 1974 areas that had not been burned for 0, 1, and 3 years were available for study.

Stem density was counted on two soils in areas last burned 0, 1, and 3 years previously. One soil was Tully silty clay loam, a well-drained and moderately well-aerated deep soil occurring on gentle to moderate slopes (4 to 8%). The other soil, Florence cherty silt loam or cherty silty clay loam, had a shallow solum on the places sampled, probably varying from 20 to 100 cm deep, with numerous large chert and limestone fragments near the surface. It was located on ridges and was nearly flat when sampled. The Tully soil was selected to represent a productive prairie soil, and the Florence a contrastingly more arid, less productive soil.

Grass and forb stems of each species were counted in 15 random 10 x 20 cm plots in each soil-treatment combination in June and early July. After counting stems, the standing dead and litter were collected by cutting at the soil surface and removing from a 0.1 m^2 circular plot that included the 10 x 20 cm stem-count plot. The standing dead and litter were weighed after being oven-dried at 60 C. The litter component was very small compared with the standing dead component.

In stem density we include clusters of leaves whose stem is at or below the soil surface, as well as those with distinct above ground stems. So called "tillers" or "shoots" are each counted as stems. Depth of standing dead was the height on a 1 cm wide white stick below which the stick was nearly obscured. Although not precise, such a measurement is sufficiently definable so that different people obtain similar readings.

In August the sampling procedure was repeated for the 0- and 3-year post-burning treatments on Tully (deep) soil. The data for the two sampling dates did not differ significantly so they were combined for further analysis. Combined one-way analysis of variance was run for stem density on the three areas for each soil with different time intervals since burning, and Pearson correlation coefficients were calculated for stem density versus amount of standing dead.

Table 1. Number of stems per square meter on deep (Tully silty clay loam) and shallow (Florence cherty silt loam or cherty silty clay loam) for 0, 1, and 3 years since burning. Within each soil, averages followed by the same letter do not differ significantly ($p < 0.05$) by F tests.

	Deep soil			Shallow soil		
	Years since burn			Years since burn		
	0	1	3	0	1	3
Total of all species	2680	1835a	1380a	2655a	2015	2680a
Tall, warm-season grasses						
Andropogon gerardii big bluestem	535a	285b	410ab	210a	330a	320a
Sorghastrum nutans Indiangrass	395a	295a	95	40a	115a	135a
Panicum virgatum switchgrass	30	0a	0a	25a	5a	5a
Mid-height, warm-season grasses						
Andropogon scoparius little bluestem	1215	605a	405a	395a	325a	350a
Panicum oligosanthes Scribner panicum	35a	15a	15a	10a	30a	5a
Bouteloua curtipendula sideoats grama	75a	15ab	2b	215a	160a	50
Sporobolus asper tall dropseed	10a	5a	90a	375a	0	415a
Short, warm-season grass						
Bouteloua hirsuta hairy grama	25a	30a	0a	50a	25a	425
Cool season grasses and sedges						
Poa pratensis Kentucky bluegrass	10a	295a	125a	845a	415b	625ab
Carex spp. & Cyperus spp. sedges and flatsedges	220a	175ab	95b	200a	385	180a
Perennial forbs						
Ambrosia psilostachya western ragweed	2a	5a	5a	0a	5ab	15b
Aster ericoides heath aster	100a	40b	85ab	50a	30a	25a
Aster oblongifolius aromatic aster	0a	5a	0a	40a	25a	0

RESULTS AND DISCUSSION

Density changes with time after burning. Stem densities of three common native prairie grasses were much reduced as a result of three years without burning on the deep soil: *Sorghastrum nutans* (Indiangrass), *Andropogon scoparius* (little bluestem), and *Bouteloua curtipendula* (sideoats grama), as was the density of all plants combined. Density of *Andropogon scoparius* was reduced even after one year without burning. Stem density of some other species declined with absence of burning, but the reductions were not significant (Table 1). The results on the shallow soil often differed from those on the deep soil (Table 1), thus emphasizing the importance of soil on plant responses. Stem density of *Bouteloua curtipendula* and *Aster oblongifolius* decreased with time after burning, whereas stem density of *Bouteloua hirsuta* and *Ambrosia psilostaycha* increased.

Correlation with amount of standing dead. On deep soil the amount of standing dead correlated significantly with stem density for ten species. Seven of the ten showed a negative correlation, meaning that stem density declined as standing dead increased (Table 2). Sometimes oven-dry weight and sometimes depth of standing dead had a higher correlation than the other with density; depth had the higher correlation 6 of 14 times on deep soil and 11 of 14 on the shallow soil. Thus, there is no obvious advantage of one measure of standing dead over the other. This was surprising because depth is more subject to personal judgment. However, it is logical that a given weight of standing dead will have more effect on new growth if the dead plants are high above the ground than if they are low, if the height to which new plants much grow to obtain ample light is critical. That may explain why depth of standing dead correlated about as well as weight with stem density. The finding has practical importance because depth can be obtained quickly, while weight is slow and tedious to measure.

Table 2. Pearson correlation coefficients between stem density and both depth of standing dead and oven-dry weight of standing dead on deep (Tully) and shallow (Florence) soils. Parentheses contain alpha values, obtained from t tests.

	Standing dead	Deep soil	Shallow soil
Total of all species	depth	-.500 (.001)	-.086 (.286)
	weight	-.573 (.001)	-.053 (.365)
Tall, warm-season grasses			
Andropogon gerardi	depth	-.174 (.068)	.144 (.172)
big bluestem	weight	-.127 (.138)	.111 (.233)
Sorghastrum nutans	depth	-.490 (.001)	.426 (.002)
Indiangrass	weight	-.535 (.001)	.334 (.012)
Panicum virgatum	depth	-.291 (.006)	-.171 (.131)
switchgrass	weight	-.287 (.006)	-.093 (.272)
Mid-height, warm-season grasses			
Andropogon scoparius	depth	-.380 (.001)	.140 (.180)
little bluestem	weight	-.473 (.001)	.060 (.348)
Panicum oligosanthes	depth	-.192 (.050)	.085 (.289)
Scribner panicum	weight	-.184 (.057)	.109 (.239)
Bouteloua curtipendula	depth	-.362 (.001)	-.385 (.004)
sideoats grama	weight	-.412 (.001)	-.372 (.006)
Sporobolus asper	depth	.143 (.110)	-.161 (.146)
tall dropseed	weight	.200 (.043)	-.123 (.210)
Short,warm-season grass			
Bouteloua hirsuta	depth	-.080 (.247)	.051 (.370)
hairy grama	weight	-.198 (.044)	.159 (.149)
Cool season grasses and sedges			
Poa pratensis	depth	.393 (.001)	-.145 (.172)
Kentucky bluegrass	weight	.383 (.001)	-.067 (.330)
Carex spp. & Cyperus spp.	depth	-.385 (.001)	.071 (.321)
sedges & flatsedges	weight	-.420 (.001)	-.030 (.423)
Perennial forbs			
Ambrosia psilostachya	depth	.105 (.184)	.296 (.024)
western ragweed	weight	.113 (.168)	.270 (.037)
Aster ericoides	depth	-.104 (.187)	-.176 (.123)
heath aster	weight	-.040 (.366)	-.168 (.135)
Aster oblongifolius	depth	.193 (.048)	-.303 (.022)
aromatic aster	weight	.004 (.487)	-.314 (.018)

BLUESTEM PRAIRIE STEM DENSITY

Although stem density of the majority of species declined with time since burning and with an increase in standing dead, a few species showed the opposite trend. Poa pratensis (Kentucky bluegrass) stem density had a highly significant positive correlation with amount of standing dead (Table 2), and increased with time after burning. This is expected, because late-spring burning is injurious to it.

Results on the shallow soil often differed from the results on the deep soil, with respect to both stem density in relation to time since burning and correlation of stem density with amount of standing dead. For the less common species this probably was due to an inadequate sample size. In addition, there may have been some influence of variable history on the different areas prior to initiation of the present burning regimes. Also, we think it probable that the variability in water supply as a result of the extreme variability in soil depth in this rocky substrate was more important than the amount of standing dead in determining stem density. If this be true, then plants would be stunted or absent on the drier spots, but larger on the moister spots. Thus one would expect a positive correlation between stem density and amount of old growth. This was found in some cases, especially in Sorghastrum nutans (Table 2). In contrast, on the deep soil where the soil is relatively uniform, a negative correlation was obtained. However, this hypothesis is not adequate for all cases, such as Bouteloua curtipendula, for which the correlation was negative on both soils. It is a smaller plant than Sorghastrum nutans, but this difference is not enough to explain the contrary results in the two species. A number of unknown influences appear to be involved.

This study confirms that stem density of dominant native tall grasses in bluestem prairie is reduced by absence of burning and apparently by accumulation of standing dead plants. Several workers have reported increases in seed stalk production as a response to burning, but only three studies are known to us that report stem density counts on burned and unburned prairie. After spending much of one growing season in obtaining stem density and amount of standing dead in the 135 small plots of this study, we understand why there are few such studies. One of the three previous studies is not comparable because the old standing dead plants were removed by raking from the unburned plots (Aldous 1934). The other two studies compared density in unburned plots with plots from which the standing dead was burned (Hulbert 1969) or removed by hand (Weaver and Rowland 1952). Removal in both studies resulted in an increase in stem density, as in the present study. However, both of these studies were in areas undisturbed for many years. Our data show that the changes are appreciable in the first three years.

The stem density of the dominant grass, Andropogon gerardii (big bluestem), declined with increasing amount of standing dead in this study, but the result was nonsignificant. However, the significant reduction in stem density of big bluestem with many-year accumulation of standing dead found in the earlier studies (Hulbert 1969, Weaver and Rowland 1952), leads us to believe that the trend is meaningful. The indication that Sorghastrum nutans and Andropogon scoparius decline in density more rapidly than A. gerardii implies that the latter, which is dominant in burned grassland, will become even more dominant when left unburned. That helps explain why, in the long undisturbed stands mentioned above, Andropogon gerardii was nearly the only grass present.

ACKNOWLEDGEMENTS

Contribution No. 1287-A, Division of Biology and Kansas Agricultural Experiment Station. This study was supported by NSF Grant GY 11241.

LITERATURE CITED

Aldous, A. E. 1934. Effect of burning on Kansas bluestem pastures. Kansas Agr. Exp. Sta. Tech. Bull. 38. 65 pp.

Hulbert, L. C. 1969. Fire and litter effects in undisturbed bluestem prairie in Kansas. Ecology 50:874-877.

Kucera, C. L., and J. H. Ehrenreich. 1962. Some effects of annual burning on central Missouri prairie. Ecology 43:334-336.

Old, S. M. 1969. Microclimate, fire and plant production in an Illinois prairie. Ecol. Monogr. 39:355-384.

Weaver, J. E., and N. W. Rowland. 1952. Effects of excessive natural mulch on development, yield, and structure of native grassland. Bot. Gaz. 114:1-19.

INDEPENDENT ASSORTMENT OF ENVIRONMENTALLY INFLUENCED CHARACTERS OF CANADA MAYFLOWER IN THE POST-GLACIAL PRAIRIE PENINSULA

David F. Grether
Department of Biology
St. Cloud State University
St. Cloud, Minnesota 56301

ABSTRACT

Canada mayflower is a woodland species of northeastern North America. It is found in northern Alberta and the Black Hills of South Dakota and eastward to the Atlantic coast and southward along the Appalachian Mountains to Tennessee. It is pubescent in the western part of its range and glabrous in the east. When the individuals with residual pubescence are mapped they extend in a corridor to the Atlantic coast. This is roughly the northern part of the former prairie peninsula. However, the characteristic of weak cross veins, usually associated with the pubescent variety, does not follow the same pattern of distribution. Pubescence appears to give plants an advantage in drier areas whereas weak cross veins do not seem as selectively important.

INTRODUCTION

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 Minnesota, Missouri Botanical Garden, University of Nebraska, U.S. National Museum, Oberlin College, Rocky Mountain, Univ. of Wisconsin) 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. This paper is concerned with the relation between pubescence and cross veins of Canada mayflower, and the geographic distribution of prairie vegetation.

METHODS AND RESULTS

The plants examined were grouped according to pubescence and type of cross veins. If the cross veins were barely noticeable they were considered weak, whereas plants having leaves with a penni-parallel reticulate appearance were considered strong. Each characteristic was plotted separately by geographic section on a map of North America. Some plants have both pubescence and weak cross veins, some have one or the other. Pubescence and weak cross veins are more characteristic of the var. interius.

Since other species also exhibit pubescence or hairiness at one end of the range and lack it on the other (Angelica atropurpurea, Lupinus 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 a particular geographic area. The map of the range was marked off in 193 km (120 mile) squares, and all the plants, both pubescent and glabrous, located within a square were used to calculate the percentage of pubescence shown on the map (Fig. 1). 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. The weak cross veins characteristic was also plotted (Fig. 2) and heavy lines were drawn similar to those in Figure 1 to compare the two characteristics. The two distribution maps show that the characteristics assort independently, and whereas cross veins show no pattern indicating the prairie peninsula, pubescence does.

DISCUSSION

In the interpretation of the differences between the two varieties, Butters (1926, 1927) 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 pecularities 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 beyone 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. The advantages of pubescence on leaves has been variously documented; with some authors, pubescence is said to aid in transpiration, while others

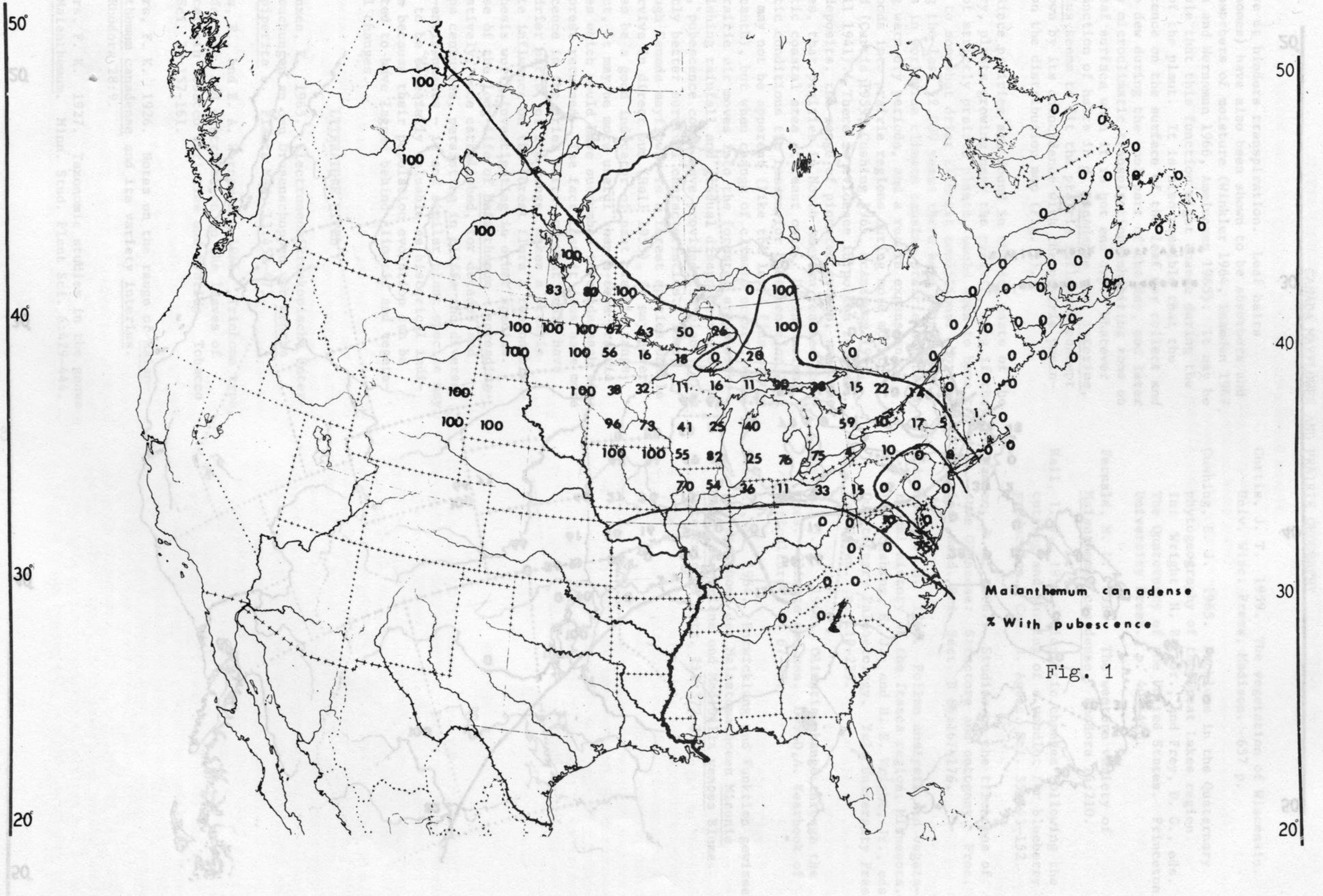


Fig. 1

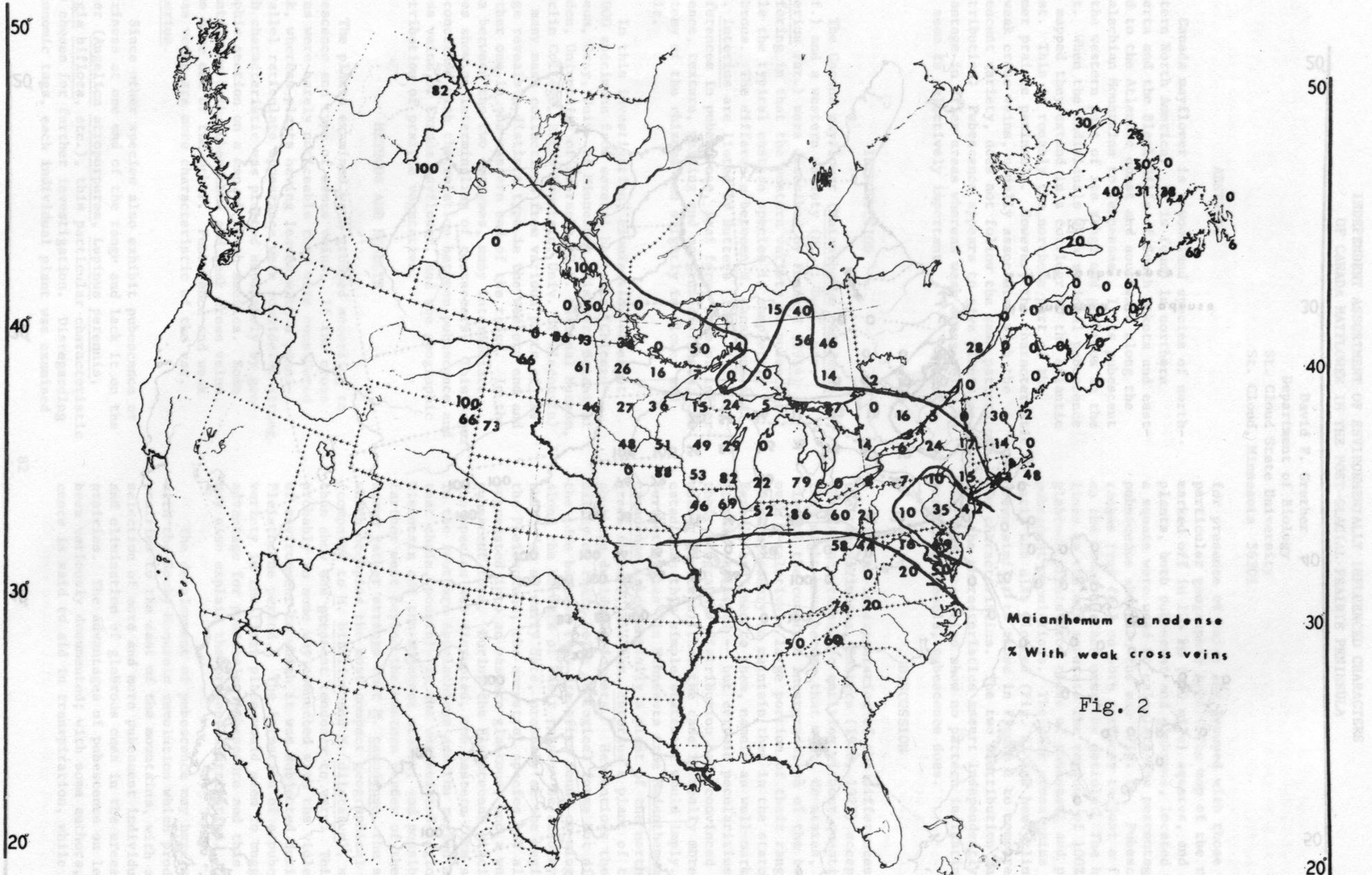


Fig. 2

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 its coincidence with the prairie peninsula on the distribution map (Fig. 1).

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 period (Curtis 1959, Cushing 1965, McAndrews 1967, Russell 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.

LITERATURE CITED

Amelunxen, F. 1965. Electronenmikroskopische Untersuchungen an den Drusenschuppen von Mentha piperita L. Planta Med. 13:457-473.

Banera, R., and E. A. Wernsman. 1966. Trichome type, density, and distribution on the leaves of certain tobacco varieties and hybrids. Tobacco Sci. 10:157-161.

Butters, F. K. 1926. Notes on the range of Maianthemum canadense and its variety interius. Rhodora 28:9.

Butters, F. K. 1927. Taxonomic studies in the genus Maianthemum. Minn. Stud. Plant Sci. 6:429-444.

Curtis, J. T. 1959. The vegetation of Wisconsin. Univ. Wisc. Press, Madison. 657 p.

Cushing, E. J. 1965. Problems in the Quaternary phytogeography of the Great Lakes region. In: Wright, H. E., Jr., and Frey, D. G., eds. The Quaternary of the United States. Princeton University Press. p. 403-416.

Fernald, M. L. 1914. The western variety of Maianthemum canadense. Rhodora 16:210.

Hall, I. V. 1955. Floristic changes following the cutting and burning of a woodlot for blueberry production. Can. J. Agric. Sci. 35:143-152.

Inamden, J. A. 1967. Studies on the trichomes of some Oleaceae: Structure and ontogeny. Proc. Ind. Acad. Sci. Sect. B 66:167-176.

McAndrews, J. H. 1967. Pollen analysis and vegetational history of the Itasca region, Minnesota. In: Cushing, E. J., and H. E. Wright, Jr., eds Quarternary Paleoecology. Yale University Press, New Haven. p. 219-239.

Russell, J. R. 1941. Climatic change through the ages. Climate and man. U.S.D.A. Yearbook of Agriculture. p. 67-97.

Winkler, S. 1964. Entwicklung und Funktion gewisser Sterntrichome der Melastomataceen Miconia magnifica Triana und Medinilla venosa Blume. Osterreiches Botz. 111:372-392.

LIFE HISTORY OF PSORALEA ESCULENTA PURSH (LEGUMINOSAE): REPRODUCTIVE BIOLOGY AND INTERACTIONS WITH A CURCULIONID WEEVIL

Sharon Hermann-Parker

Iowa Lakeside Laboratory, and
Department of Biological Sciences
University of Illinois at Chicago Circle
Chicago, Illinois 60680

ABSTRACT

Populations of Psoralea esculenta Pursh, a long-lived prairie legume that occurs in xeric habitats in northwestern Iowa, contain flowering, nonflowering and dormant plants. Flowering plants produce 30-40 buds, on the average, in the early spring. These buds are attacked by a host-specific curculionid weevil, whose larvae feed upon the developing flower parts. In two populations studied in 1976, seed production, on the average, was reduced 10-55 percent by the weevils. An average of 6-12 seeds were produced per plant. Extensive infestation by weevils also reduced seed set because the remaining flowers were not likely to be pollinated. Nonflowering plants remain photosynthetically active 1.5 times as long as flowering plants; the latter abscise at the base, by midsummer, and disperse seeds by tumbleweeding.

P. esculenta exhibits life history characteristics (few offspring produced annually, but over a long life span) similar to those of other organisms in closed, equilibrium communities, for which the annual likelihood of reproductive success is low. Other life history characteristics appear to be the result of a xeric environment and short growing season. Selection for intermittent, rather than annual, seed production in such an environment might result from 1) additional resources being obtained over the life span for investment in large-sized offspring, capable of becoming established in a xeric environment, and 2) reduction of the herbivore impact upon plant fecundity.

INTRODUCTION

This study describes a native prairie legume, the prairie turnip, Psoralea esculenta Pursh (Leguminosae), and its host-specific curculionod weevil. Questions of particular interest include: 1) What is the impact of the environment and of the weevil on P. esculenta seed production; 2) What adaptations of the plant enhance reproductive success and/or reduce the potential impact of the weevil; 3) What is the relationship between adaptations for reproduction and those that reduce losses to the weevil; and 4) Are these adaptations similar to those of legumes in other habitats?

METHODS

The two study sites used for this project are located in Dickinson County, northwestern Iowa. The Cayler Prairie Preserve is a 64 ha (160 acre) state preserve that has never been plowed. One 12 ha section was grazed until about twenty years ago (in the 1950's), but the majority of the preserve is virgin prairie (Aikman and Thorne 1956, Platt 1975). Topography of the prairie is characterized by alternating gravel eskers and swales. The second study site is the Freda Haffner Preserve (owned by The Nature Conservancy), which includes a large kettle hole (Salisbury and Knox 1969). Up until 1973, all of this 48 ha (120 acre) prairie was grazed.

General observations on the life histories of the organisms were conducted from 1974 to 1976. Individual plants were permanently marked and numbered. In 1976, individual plants from one area each on the Cayler Prairie and Freda Haffner Preserves were mapped. The areas, dry ridge tops, were 68 by 16 meters (Cayler Prairie Preserve) and 80 by 15 meters (Freda Haffner Preserve). The size and shape of each area used was determined by the distribution of the plants in the populations of P. esculenta. Other P. esculenta were located twenty to fifty meters from these areas, on neighboring ridge tops. From the mapping of individuals in the two populations, interplant distances were estimated.

The insects in this study include a weevil (Coleoptera; Curculionidae) and two wasps (Hymenoptera; Chalcidoidae). These insects have not yet been identified to species.

RESULTS AND DISCUSSION

Life History of Psoralea esculenta

Psoralea esculenta is a perennial herb with a wide geographic distribution in prairies and grasslands of the midwest, from Alberta, Minnesota and Wisconsin south to Texas and New Mexico. Adults in Dickinson County, Iowa, typically range from 0.10 to 0.25 m high; Weaver (1954) gives a maximum height of 0.50 m. The tap root is about 5 cm in diameter near the surface and extends 1-2 m down into the soil (Weaver 1919, 1920; Weaver and Albertson 1956). Mature plants are long-lived, probably 15-20 years or more.

Populations of P. esculenta contain flowering, nonflowering and dormant individuals. Approximately 10% of the plants in each population remain dormant during a given year; these individuals reemerge the following year (rarely after two years). Between 40% and 60% of the plants that break dormancy do not flower in a given year (Table 1); many of those individuals that do not flower break dormancy in late June, and often remain green and photosynthetically active into the first half of August. These individuals frequently flower in subsequent years. Most flowering individuals break dormancy in May and are in bloom before or during the first half of June, depending upon ambient air/soil temperature. The light blue flowers are approximately 2 cm long and are in tight inflorescences of 5 to 40 flowers. As many as 5 or 6 inflorescences may be present on especially large plants, although 1 to 3 is the rule at the sites studied. Between 30 and 40 flower buds, on the average (Table 1), are produced per plant. Pollination is by small bumblebees and solitary

Table 1. Population data[a] for Psoralea esculenta in 1976.

	Cayler Prairie Preserve	Freda Haffner Preserve	"t"=
Number of nondormant plants	59	75	
Number of flowering plants	36	29	
% of the population that flowered[b]	61.0	38.7	
Nearest neighbor distance (in meters), total population	2.28 ± 0.21	1.36 ± 0.11	4.020**
Nearest neighbor distance (in meters), flowering population	3.33 ± 0.48	2.24 ± 0.26	1.837
Mean number of flower buds per flowering plant	38.83 ± 3.67	31.97 ± 4.25	1.240
Mean number of flower buds infested with weevils per flowering plant	21.28 ± 2.93	3.21 ± 1.65	5.034**
Mean number uninfested flower buds (ie., flower that opened) per flowering plant	16.72 ± 2.94	28.86 ± 4.03	2.495*
Mean number of seeds per flowering plant	6.83 ± 1.41	12.48 ± 2.02	2.358*
% seed set (based on the number of flower buds)[c]	17.6	39.0	

[a] ± S.E. where applicable

[b] $X^2 = 6.604$, significant at $X^2_{.99}$

[c] $X^2 = 132.828$, significant at $X^2_{.999}$

** $p < .001$

* $p < .05$

all others not significant

bees. Plants enclosed in cages that excluded these insects produced no seeds; apparently insects are necessary for pollination. Each pollinated flower produces a single large dark brown seed. Seed dispersal, which occurs from the middle to the end of July, is accomplished by a tumbleweed mechanism, like other members of the genus (Becker 1968). Abscission of the main stem occurs just below ground level, and the above ground portion of the plant is blown by the wind. If the litter is deep, however, the plant and seeds may remain trapped in place. Individual inflorescences also occasionally abscise.

Patterns of annual above-ground growth observed in P. esculenta suggest that annual production and dispersal of seeds is not crucial to reproductive success (and thus fitness). Recruitment of seedlings into the populations of P. esculenta does not occur annually. Over the three year period of study, no seedlings were found at either study site. Being long lived, P. esculenta can tolerate infrequent seedling establishment. Germination and/or establishment may be dependent upon specific environmental conditions, such as above average precipitation. Similar requirements for germination/establishment are suggested for some other legumes (Martin and Cushwa 1966). Infrequent recruitment has also been recorded for other plant populations. Harris (1967) has shown that seedlings of a bunch grass, Agropyron spicatum, survive competition only in summers of above average rainfall. Antevs (1948) indicated that recruitment into plant populations of Artemisia-dominated communities in the Great Basin of Utah occurs irregularly, during years of maximal precipitation.

If seedling recruitment into populations of P. esculenta occurs infrequently, then dormancy of adults and/or non-flowering in any given year probably does not significantly reduce the chance of reproductive success of an individual plant. Moreover, non-flowering plants remain photosynthetically active half again as long as those plants that flower and then go dormant

Table 2. Effects of weevil infestation on the reproductive output of Psoralea esculenta on the Cayler Prairie Preserve in 1976[a]

	Number of plants	Number of plants setting seed	Number of seeds per number of open flowers[b]	Mean number of seeds per open flower
Plants with ≥ 10 Flowers Opening	19	18	310/498	0.62
Plants with < 10 Flowers Opening	17[c]	4	13/52	0.25

[a]The Freda Haffner Preserve population is not included; only one plant in that population produced < 10 flowers.

[b]$X^2 = 26.78$, significant at $X^2_{.999}$

[c]Two of these plants had no open flowers and thus the lack of seed set in these plants was not a function of pollinator behavior. Fifteen of the seventeen plants had > 10 flower buds, but < 10 open flowers, due to weevil infestation.

for dispersal of seeds. A plant that does not flower during one season obtains additional energy or resources that are likely to be stored for use during the subsequent year(s). This intermittent reproduction, with an increased output of seeds due to additional stored energy, might increase fitness over annual production of fewer seeds (cf. Nichols et al 1976). Also, environmental cues may be involved. Rapid warming of the soil, in the spring after a fire, might signal plants that dispersal of seeds can occur over a large area, as opposed to an unburned area where litter might hinder tumbleweeding. High moisture content of the soil might be a signal indicating that the chances of seed germination and/or establishment of seedlings are increased. Thus, dormancy and not flowering may be adaptive because 1) increased reproductive output over the life span occurs as a result of time spent in dormant and nonflowering states, and 2) increased reproduction after a fire and/or in moist years might increase the likelihood of reproductive success over the life span.

Insect Life Histories

The life history of the curculionid weevil is closely integrated with that of P. esculenta; this weevil is host specific on the Cayler Prairie and Freda Haffner Preserves. It emerges as an adult in the spring, at the same time or slightly later than the plant. The weevils literally sit on the plants, feeding and copulating, until the inflorescences develop. During the first week of June, the male weevils disappear and presumably die; the females, which are considerably larger than the males, persist for one to two weeks more. During this time, they oviposit on the flowers of Psoralea. Just before the flowers are ready to open, a single egg is laid per flower. The larva hatches and seals itself in the corolla by making a little cap at the top. It devours the ovary and all other flower parts. The flower never opens; only the calyx and the cap remain. Tatschl (1970) observed similar larval behavior of Apion oblitum (Curculionidae) on P. tenuiflora and P. floribunda. The larva pupates in the chamber formed by the calyx and cap, and exits as an adult in late June to early July. In the laboratory, newly hatched adults feed on P. esculenta leaves. Recently hatched adults, in the field, burrow into the ground near the host plant; presumably they overwinter there. The weevil makes a distinctive exit hole in the calyx and this permits accurate censusing of weevil density.

There is a second order interaction involving two species of parasitic wasps that lay eggs, singly, on the weevil larvae. The wasp larva develops after the weevil larva has eaten most of the flower parts. The wasp immobilizes the weevil larva, eventually killing it, and pupates in the chamber that the weevil made. The adult wasp makes an exit hole similar to that of the weevil but much smaller. Aging of the calyx distorts the size of this hole and makes censusing more difficult than for the weevil.

The parasitic wasps may have the potential for reducing the density of the weevils. In 1976, the wasp populations did not appear to be large enough to have much impact, particularly on the Freda Haffner Preserve, which may be an indication of past disturbances.

Plant-Weevil Dynamics

Weevil populations differed on the two areas included in this study. Although the density of all plants was greater on the Freda Haffner Preserve than on the Cayler Prairie Preserve, the density of flowering plants and the average total number of flower buds per reproducing plant were not statistically different on the two study areas (Table 1). In 1976, however, individual flowering plants on the Freda Haffner Preserve averaged 10% of the flowers per plant infested with weevils, whereas plants on Cayler Prairie Preserve averaged 55% of the flowers per plant infested with weevils (Table 1). Almost seven times as many weevil larvae were present per plant on the Cayler Prairie Preserve as on the Freda Haffner Preserve. Although a similar proportion of the uninfected flowers per plant (41-43 percent) set seed on both areas, on the Freda Haffner Preserve the reproductive output, measured as the number of seeds per plant, was about twice that on the Cayler Prairie Preserve (Table 1). If a larger effective fecundity of a plant increases the likelihood of reproductive success, individuals in the population on the Freda Haffner Preserve will be more likely to leave offspring than will individuals in the population on the Cayler Prairie Preserve. For example, as the plant tumbleweeds down slopes on the prairie, having more seeds might result in dispersal of offspring over a wider range of environmental conditions; thus, the likelihood of offspring being located on sites suitable for germination and establishment might be increased.

Weevils also affect fecundity of P. esculenta indirectly by affecting the likelihood that flowers will be pollinated. If a plant is heavily attacked by weevils, and thus a large proportion of the flowers do not open, the remaining flowers may not be pollinated. Data from the population on the Cayler Prairie Preserve (Table 2) illustrate the difference between plants with ten or more flowers, compared to those with fewer than ten flowers opening. More plants set seed and the number of seeds per flower was greater when ten or more open flowers were present on a plant. If ten or more flowers were open on a plant, those open flowers set seed 62 percent of the time. When less than ten flowers were open, they only had a 25 percent chance of setting seed. A threshold effect, in which pollinators visit a plant only if it has sufficient flowers (ten or more) is likely.

Although the resource utilized by the weevil for reproduction, flowering plants in the P. esculenta populations, is present at similar densities on the Cayler Prairie and Freda Haffner Preserves, the density of all plants in the P. esculenta populations (measured as the nearest neighbor, Table 1) is different on the two areas. Because all P. esculenta individuals can be utilized as a food source by adult weevils, nonflowering plants could serve as "stepping stones" during insect dispersal. However, little is known about the dispersal of the weevil. Newly hatched adults disappear before P. esculenta becomes a tumbleweed, eliminating this as a possible dispersal mechanism. Flight of the weevils has been observed in the laboratory, but not in the field. The greater proportion of plants flowering on the Cayler Prairie, compared to the Freda Haffner Preserves, also indicates that the more extensive infestation by weevils on the former area is not due solely to dispersal from nonflowering to flowering plants. If this were the case, higher densities of weevils per plant would have been expected on the Freda Haffner Preserve. Instead, the difference between infestations on the two sites appears to be the result of different densities of weevils in the two populations.

The past history of disturbances at each site offers insight into the differences in insect infestation recorded in this study. The Freda Haffner Preserve was heavily grazed until 1973. This grazing would depress the weevil population; cattle feed upon the plants (Weaver 1968) before inflorescences are developed or weevils have matured. The low proportion of flowering plants on the Freda Haffner Preserve (Table 1) suggests that reproduction in P. esculenta was depressed by grazing of the plants. In contrast, the plant and insect populations on the Cayler Prairie Preserve are close to equilibrim. In the past, only a fraction of it was grazed. The extensive areas not disrupted undoubtedly served as sources for recolonization of P. esculenta populations, in the grazed portion, by the weevil.

Evolution of Life History Characteristics of Psoralea esculenta

Both abiotic and biotic factors have the potential to mold the life histories of organisms. Dobzhansky (1950) has suggested that the relative importance of abiotic and biotic factors is different in temperate and tropical systems. In temperate regions, selection is thought to be primarily a function of abiotic factors and, indeed, prairie species are highly adapted to withstand environmental stresses of fire and drought (cf. Weaver, Stoddard and Noll 1935, Aikman 1955, Hill and Platt 1975). For P. esculenta, the life history appears to include evolutionary responses to a xeric environment. A short growing season, in part due to the xeric environment and in part due to seed dispersal by tumbleweeding, is also likely to be important. Limited time each season for obtaining resources used in reproduction, coupled with the advantages provided by large-sized seeds in a xeric environment (cf. Baker 1972, Harper et al 1970, Kneebone 1957, Platt and Weis 1977, Werner and Platt 1976, Wright 1966) indicates that reproductive output or the number of offspring produced per plant will be small (both annually and over the life span). In addition, weevils can lower the reproductive output of a plant even more, both directly by eating the developing flowers and indirectly by reducing the chances of pollination. Thus, the combination of abiotic factors (xeric environment and short growing season) and biotic factors (weevil herbivory) should act as strong selection pressures upon those life history characteristics of P. esculenta involved in reproduction.

Comparison of adaptive life history characteristics of P. esculenta with those of tropical and other temperate legumes (in both cases where the abiotic variables are presumably less severe) facilitates delineation of how the abiotic variables may restrict the range of potential evolutionary responses to the attack by a host-specific weevil.

The xeric environment of P. esculenta would favor individuals in the population that produce large seeds. Consequently, small seeds that would not support the larva of a weevil (Janzen 1969) is not feasible as a means of escape from weevil attack in this species. Small seeds would be more feasible for species of Psoralea inhabiting more mesic prairie environments, however. P. argophylla Pursh, a congener, which, on the Cayler Prairie and Freda Haffner Preserves, is present on the more mesic prairie midslopes, produces much smaller seeds than does P. esculenta. No weevils have been observed to attack the flowers or seeds of this species.

Production of large-sized seeds, if resources available for seed production are limited, has been suggested to result in production of fewer seeds per plant (Werner and Platt 1976). P. esculenta appears to fit this pattern. Both the short growing season in a xeric habitat and the use of tumbleweeding as a means of seed dispersal, limit the amount of resource obtainable by a plant during a single growing season. Consequently, weevil satiation (by producing large numbers of ovules and/or seeds and thus increasing the probability that some will escape the weevil) appears unlikely for P. esculenta. Janzen (1971a) has postulated that Cassia grandis L., a woody legume of deciduous forests in Central America, escapes attack by Bruchid weevils in this manner. Similar adaptations might be utilized by some temperate legumes. Large clumps (ie. large genetic individuals) of Astragalus canadensis L. on the Cayler Prairie Preserve produce large numbers of seeds (Platt et al 1974) and may have some seeds escape attack by weevils via satiation. Other species of Psoralea may satiate weevils. P. tenuiflora Pursh and P. floribunda Pursh produce as many as 20,000 flowers per plant (clone or genet, sensu Harper and White 1974), and most of the flowers are dropped before fruits develop (Tatschl 1970).

Resource limitation in P. esculenta also is suggested by the determinate nature of flowering. Flower buds are already formed when the plants emerge in the spring. The growing season is so short that no time is available for production of additional flowers, even if environmental conditions are favorable (ie., a year with above average rainfall). Consequently, indeterminate flowering (extension of the time of flowering might enable the plant to produce flowers that would not be attacked by the insect) cannot be used as a means of escape from weevil attack, as proposed by Janzen (1971b) for tropical plants. P. esculenta is so determinate in its annual growth patterns, that flowering plants abscise even if they set no seed. Thus, the plant responds neither to weevil attack nor to favorable growing conditions by extending the time spent in a nondormant state.

The short growing season and determinate pattern of annual above-ground growth in P. esculenta also eliminates staggered production of seeds as a mechanism to escape attack by weevils. Janzen (1969) has suggested that in tropical legumes, asynchronous flowering by legumes may result in escape from attack by weevils.

Two other mechanisms of minimizing the effects of an insect pest, chemical defense for the host plant and biological control, have often been recorded in the literature. Chemical defenses have been noted for many legumes (Janzen 1969), especially in tropical species. The possibility of toxicity in P. esculenta, while unstudied, is very real. This would not be expected to exclude all herbivores, however, but would decrease the herbivore load (Root and Olson 1969). Such toxic compounds also have the potential of lowering reproductive output, if there must be energy allocated for their production.

The potential for biological control is also very real; wasp larvae parasitizing the weevil larvae have been observed. Janzen (1971b) notes that there is "almost no evidence of entomophagous parasites of tropical host specific seed predators." The parasites of northern insect pests warrant closer study; in some cases their effects may be subtle but important.

Although prairies are of relatively recent origin (compared to other biomes), they are closed communities close to equilibrium (cf. Platt 1975, Werner and Platt 1976). Consequently, adaptive life history characteristics of prairie plants resemble those of species in other closed communities. P. esculenta, in this respect, is typical of most prairie plants. Even more striking, however, are resemblances of P. esculenta to animals in which extreme resource limitation occurs (California condor, Mertz 1971; oceanic sea birds, Goodman 1974); such organisms, adapted to withstand a low annual likelihood of reproductive success, produce few offspring annually and reproduction occurs over a long life span. In addition, P. esculenta exhibits life history characteristics that appear to be adaptations to the physical environment that characterizes prairies. Large sized seeds and, in part, a greatly compressed growing season reflect the xeric nature of the habitats in which P. esculenta occurs. Also, dispersal of offspring via tumbleweeding is an adaptation exhibited by plants only in environments in which high wind speeds occur frequently.

Fitness of individual plants in populations of P. esculenta, as indicated by the results of this study, will be maximized by adaptations that reduce the loss of potential offspring to herbivory, while concurrently optimizing that chances that offspring produced will survive to maturity. The constraints imposed by inhabiting a xeric environment, coupled with a short growing season, appear to restrict greatly the possible evolutionary responses to selection pressures imposed by the weevil that feeds upon the developing flowers of P. esculenta.

Intermittent reproduction may be an adaptive characteristic of P. esculenta that increases the chances of reproductive success 1) in an environment in which resources available for production of offspring are limited, but in which the abiotic factors involved nessitate a large investment by the parent plant in the offspring, and 2) when host-specific herbivores potentially can affect greatly the fecundity of the plant.

Over the life span of P. esculenta, production of offspring may be increased by intermittent reproduction. Those resources utilized for reproduction may be increased by not flowering periodically, and thus remaining photosynthetically active for a much longer time during the growing season. Increased resources utilized intermittently for reproduction might be especially beneficial if flowering were cued in some way as to when the chances of reproductive success were increased (as for example, increased dispersal capability following a fire).

Intermittent reproduction may also decrease the impact of weevil herbivory upon plant fecundity. When not flowering, the weevil load is reduced. Because the dispersal capacity of the weevil appears to be limited, in the years after ones in which no flowering occurred or in which the plant remains dormant, the chances of producing offspring are likely to be increased. If additional resources garnered when not flowering are invested in seed production at that time, then the effective fecundity of the plant might be increased further.

ACKNOWLEDGEMENTS

The Iowa Preserves Board and Conservation Commission cooperated with the use of the Cayler Prairie Preserve, as did The Nature Conservancy with the Freda Haffner Preserve. I am indebted to Robert Cruden, James Nash and Blake Parker for encouragement and assistance in the field. Robert Cruden and especially William Platt provided useful criticisms and editorial comments on the manuscript. This study was started as a project for a master's program, under the direction of R. Cruden, while I was a student in the Department of Botany at the University of Iowa. Portions of this study were supported by NSF grant DEB 76-10411, W. J. Platt and I. M. Weis, principal investigators.

LITERATURE CITED

Aikman, J. M. 1955. Burning in the management of prairie in Iowa. Proc. Iowa Acad. Sci. 62:53-62.

Aikman, J. M., and R. F. Thorne. 1956. The Cayler Prairie: An ecologic and taxonomic study of a northwest Iowa prairie. Proc. Iowa Acad. Sci. 63:177-200.

Antevs, E. 1948. The Great Basin III--Climatic changes and pre-white man. Bull. Univ. Utah 38: 168-191.

Baker, H. G. 1972. Seed weight in relation to environmental conditions in California. Ecology 53: 997-1010.

Becker, D. A. 1968. Stem abscission in the tumbleweed, Psoralea. Amer. J. Bot. 55:753-756.

Dobzhansky, T. 1950. Evolution in the tropics. Amer. Sci. 38:209-221.

Goodman, D. 1974. Natural selection and a cost ceiling on reproductive effort. Am. Nat 108: 247-268.

Harper, J. L., P. H. Lovell, and K. G. Moore. 1970. The shapes and sizes of seeds. Ann. Rev. Ecol. Syst. 1:327-356.

Harper, J. L., and J. White. 1974. The demography of plants. Ann. Rev. Ecol. Syst. 5:419-463.

Harris, G. A. 1967. Some competitive relationships between Agropyron spicatum and Bromus tectorum. Ecol. Monogr. 37:89-111.

Hill, G. R., and W. J. Platt. 1975. Some effects of fire upon a tall-grass prairie plant community in northwestern Iowa. In: M. K. Wali, ed., Prairie: A multiple view. Univ. N. D. Press, Grand Forks. p. 103-113.

Janzen, D. H. 1969. Seed-eater, versus seed size, number, toxicity and dispersal. Evol. 32:1-27.

Janzen, D. H. 1971a. Escape of Cassia grandis beans from predators in time and space. Ecology 52: 964-979.

Janzen, D. H. 1971b. Seed predation by animals. Ann. Rev. Ecol. Syst. 2:465-492.

Kneebone, W. R. 1957. Selection for seedling vigor in native grasses under artificial moisture stress. Agron. Abstr. p. 55.

Martin, R. E., and C. T. Cushwa. 1966. Effects of heat and moisture on Leguminous seed. Proc. Fifth Ann. Tall Timbers Fire Ecol. Conf. p. 159-175.

Mertz, D. B. 1971. The mathematical demography of the California condor population. Am. Nat. 105: 437-453.

Nichols, J. D., W. Conley, B. Batt and A. R. Tipton. 1976. Temporally dynamic reproductive strategies and the concept of r- and K-selection. Am. Nat. 110:995-1005.

Platt, W. J. 1975. The colonization and formation of equilibrium plant species associations on badger disturbances in a tall-grass prairie. Ecol. Monogr. 45:285-305.

Platt, W. J., G. R. Hill and S. Clark. 1974. Seed production in a prairie legume (Astragalus canadensis L.). Oecologia 17:55-63.

Platt, W. J., and I. M. Weis. 1977. Resource partitioning and competition within a guild of fugitive prairie plants. Am. Nat. 111:479-513.

Root, R. B., and A. M. Olson. 1969. Population increase of the cabbage aphid, Brevicoryne brassicae, on different host plants. Can. Ent. 101:768-773.

Salisbury, N. E., and J. C. Knox. 1969. Glacial land forms of the big kettle locality, Dickinson County, Iowa. Development Ser. Rep. 6. Iowa State Advisory Board for Preserves, Des Moines. 11 p.

Tatschl, A. K. 1970. A taxonomic and life history study of Psoralea tenuiflora and Psoralea floribunda in Kansas. Ph.D. Thesis, University of Kansas, Lawrence.

Weaver, J. E. 1919. The ecological relations of roots. Carnegie Inst. Wash. Publ. No. 286. 128 pp.

Weaver, J. E. 1920. Root development in the grassland formation. Carnegie Inst. Wash. Publ. No. 292. 151 p.

Weaver, J. E. 1954. North American prairie. Johnsen Publ. Co., Lincoln, Neb. 348 p.

Weaver, J. E. 1968. Prairie plants and their environment. Univ. Neb. Press, Lincoln. 276 p.

Weaver, J. E., and E. W. Albertson. 1956. Grasslands of the Great Plains. Johnsen Publ. Co., Lincoln, Neb. 395 p.

Weaver, J. E., L. A. Stoddard and W. Noll. 1935. Responses of the prairie to the great drought of 1934. Ecology 16:612-629.

Werner, P. A., and W. J. Platt. 1976. Ecological relationships of co-occurring goldenrods (Solidago: Compositae). Am. Nat. 110:959-971.

Wright, L. N. 1966. Drought tolerance evaluation among range grass genera, species, and accessions of three species using program-controlled environment. Proc. 9th Int. Grassland Congr., 1965. 1:165-169.

CLONING NATIVE PRAIRIE PLANTS BY TISSUE CULTURE[1]

D. J. Holden
B. E. Ellis
and
C. H. Chen

Botany-Biology Department
South Dakota State University
Brookings, South Dakota 57006

ABSTRACT

Tissue culture techniques were used to propagate native priaire plants. Of the 22 species studied nine produced plantlets, and six of these species were successfully established in the field. Five dicot and two monocot species produced plantlets via organogenesis with shoots, then roots, developing. Two dicot species developed by embryogenesis.

INTRODUCTION

Recent efforts to locate and list endangered plant species (e.g., Schumacker 1976), together with the recent activity to preserve natural areas and ecosystems (Cain 1968, Darnell 1976, Humke 1975), lead to one direct conclusion: natural areas and protected ecosystems are the remaining reservoir for the preservation of our plant heritage (Harlan 1975, Holden and Sorensen 1972). It is in these unique areas that the conservation of genetic systems and the preservation of diversity is helping determine the parameters of the life support systems for all creatures (Humke 1975, Stone 1965). It is here where our endangered and threatened plants are making their last stand (Jenkin 1975). In fact, many plants which should be a part of the system have already been lost (Gosnell 1976). To prevent further loss of genetic diversity and the actual extinction of some species, we must relocate them in selected ecosystems (Jacobsen 1975). Since transplanting wild plants is not practical and since seed collection is often not a successful operation (Sorensen and Holden 1974), we have chosen cloning in tissue culture to propagage native prairie plants. This method of vegetative propagation is the most effective and the least destructive to plants. From a small leaf as an explant several small plantlets can be induced after a short period of cultivation (Ellis 1975). We can, in 3 to 6 months, be highly successful in propagating some species by tissue culture.

METHODS

We used two media, both of which contained Murashige and Skoog (MS) (Murashige 1974) basal medium but different hormone concentrations, to screen dicotyledonous plants for cloning response. Medium I was 3 ppm kinetin (K) and 0.1 ppm napthalene acetic acid (NAA). Medium II was the reverse, with 2 ppm NAA and 0.1 ppm kinetin. Most plants, if the right explant was selected, responded to one of these media. After growth of callus was obtained, a lowering of the hormone usually produced new plantlets by either organogenesis or embryogenesis (Butenko 1968, Ellis 1975, Murashige 1974, Street 1974, White 1965).

For propagating monocotyledonous plants the culture media were Linsmaier and Skoog (RM) (Murashige 1974) or MS basal medium supplemented with 5 ppm of 2,4-D or NAA. The explants were primarily young leaves (Chen and Holden 1975, Ellis 1975), which were disinfected with 1% calcium hypochlorite for 4-15 minutes and washed in sterile water before inoculating. Young floral parts (Chen and Holden 1975) or segments of unemerged inflorescence (Chen et al, unpublished) also proved to be excellent inocula, since they were enclosed in layers of foliage leaves. Surface sterilization with 70% ethanol alone or in combination with calcium hypochlorite solution for a relatively short period of time did not injure the explant.

After plantlets grew in culture, we placed them under artificial light or in the greenhouse. After establishment in the greenhouse, plants were then divided and placed in a preselected site. It may be desirable to grow the plants under cultivated conditions for a few years to obtain a quantity of seed before introduction into the native habitat.

Plant material was obtained from the Sioux Prairie, a 200-acre prairie 20 miles south of Brookings, S.D., or from the grass nursery on the Agronomy Farm at the South Dakota State University.

RESULTS

Results are summarized from recent research at our laboratory in Table 1. It should be noted that there were two methods of development of new plantlets, organogenesis in which shoots were produced followed by roots (Chen et al, unpublished; Ellis 1975) and embryogenesis (Ellis 1975) with bulbet formation being a special type of organogenesis (Chen and Holden 1975).

Twenty-two species were cultured, with nine producing plantlets. From these nine, six have been established in the field. Five have flowered and are in their second year (Table 2).

DISCUSSION

Propagation of native prairie plants by tissue culture was successful. The value of this technique lies not only in preserving a broad genetic base, but also in preserving unique combinations of characters possible only through cloning. Nine of the 22 species studied produced plantlets. The ease by which dicot plantlets were produced are rated in the following order: Rudbeckia serotina, Ratibida columnifera, Echinacea angustifolia, Ratibida columnifera fa. pulcherrima, Asclepias tuberosa, Phlox pilosa and Zizia aptera. The two monocots tested also produced plantlets readily but required a higher level of auxin. A total of six species, five dicots and two monocots, were established in the field. These were more vigorous than their priaire counterparts.

Success in producing plantlets with medium I

[1]Published with approval of the Dean and Director of the South Dakota State University Agricultural Experiment Station as Journal Series No. 1452.

Table 1. The responses of leaf and flower tissues to various culture media.

Dicot Species	Medium[d]	Response
Achillea millefolium ssp. *lanulosa*[a] Western yarrow	I	Leaf curl[c]
	II	Brown callus
Anemone patens[a] Pasque flower	I	No response
	II	Brown callus
	2,4-D CM	No response
Artemisia frigida[a] Prairie sagewort	I	Leaf curl
	II	Roots
	2,4-D CM	Callus
Asclepias tuberosa[b] Butterfly milkweed	I	Embryos
	II	Callus
	II CM	Callus
Cicuta maculata[b] Water hemlock	I	Leaf curl only
	II	No response
Echinacea angustifolia[a] Purple coneflower	I	Shoots, roots
	II	Callus
Geum triflorum[a] Torch flower	I	No response
	II	No response
Liatris spicata[a] Dotted gay-feather	I	Callus, roots
	II	Callus, roots
	10 K	Callus, roots
	30 K	Callus, roots
Oenothera biennis[a] Evening primrose	I	Brown callus
	II	Roots
Pedicularis canadensis[a] Common lousewort	I	Leaf curl
	II	Brown callus, roots
	2,4-D CM	Callus
Penstemon grandiflorus[b] Shell-leaf penstemon	I	Leaf curl
	II	Callus, roots
	2,4-D CM	Callus
Phlox pilosa[a] Downy phlox	I	Shoots
	II	Roots
	II CM	Callus
Ratibida columnifera[a] Yellow prairie coneflower	I	Shoots
	II	Callus, roots
Ratibida columnifera fa. *pulcherrima*[a] Red prairie coneflower	I	Shoots
	II	Callus, roots
Rudbeckia serotina[b] Brown-eyed Susan	I	Shoots
	II	Roots
Senecio aureus[a] Golden groundsel	I	Leaf curl
	II	No response
Solidago rigida[b] Goldenrod	I	Leaf curl
	II	Callus, roots
	2,4-D CM	Callus
Viola nuttallii[a] Nuttall violet	I	Leaf curl
	II	Callus, brown
Viola pedatifida[a] Prairie violet	I	Leaf curl
	II	Callus, brown
Zizia aptera[a] Golden Alexander	I	Callus
	II	Embryo

Table 1 (continued)

Monocot Species	Medium	Response
Lilium philadelphicum[a]	II[e]	Bulblets
Wood lily	2,4-D, K 1/1 ppm	Callus
Andropogon gerardii[a]	2,4-D[e] 1 ppm	Shoots
Big blue stem	2,4-D 5 ppm	Callus

[a] Field collected leaves were the source of explants.

[b] Laboratory grown seedling leaves were the source of explants.

[c] A typical leaf curl response.

[d] See text; CM indicates that 10% coconut milk was added to the medium.

[e] For additional details on monocot culture see (Chen and Holden 1975; Chen et al, unpublished).

Table 2. Response of plantlets when transplanted in the field.

Species	Common Name	Response 1st year	Response 2nd year
Andropogon gerardii	Big blue stem	V[a]	F[d]
Asclepias tuberosa	Butterfly milkweed	V	F[e]
Echinacea angustifolia	Purple coneflower	F[b]	F
Lilium philadelphicum	Wood lily	V	F
Ratibida columnifera	Yellow prairie coneflower	F	F
R. columnifera fa. pulcherrima	Red prairie coneflower	F	F
Rudbeckia serotina	Brown-eyed Susan	F	F
Phlox pilosa	Downy phlox	U[c]	U
Zizia aptera	Golden Alexander	U	U

[a] Vegetative (V)

[b] Flowering (F)

[c] Unsuccessful in transplanting (U)

[d] Incomplete data

[e] One plant

(high K) was greater than with medium II (high NAA), with six species responding to the former and only one dicot and two monocots to the latter. Seven of the species produced plantlets via organogenesis and two species via embryogenesis. Five species produced good friable callus and adventitious roots, but no shoots were noticed. Additional work on these species may result in plantlets being produced. Two species, A. tuberosa and Lilium philadelphicum, require at least one overwintering period after field establishment to produce flowers. Eight of the species were either non-responsive or produced atypical growth patterns. Altering the environmental conditions or the morphological location of the explant source may result in the successful establishment of these species.

Using leaves or young flower parts from seedlings grown in the laboratory was more successful than selecting leaves from the field. The contamination rate on leaves from the field was over 90% while it was less than 10% for laboratory grown seedlings.

We believe this technique for propagating endangered species is particularly valuable. It would also be desirable to culture genetic variations found in the field, e.g., the range of colors (from dark purple to cream) found in Liatris spicata or the yellow to red petals in Ratibida columnifera to R. columnifera fa. pulcherrima.

While propagation of prairie plants by tissue culture was successful, additional work is needed. This paper summarizes some of the guidelines whereby routine cloning of a species may be possible.

Future efforts will continue along the following lines: (1) collection of endangered plant species, either as seed or as fresh leaves, from cooperating agencies in South Dakota or other states; (2) cloning of this material by tissue culture with eventual return of plants to the cooperating agency; (3) cloning and then placement in horticultural gardens at this or other institutions; (4) increase of seed of cloned plants; (5) doubling of chromosomes and selection of desirable genetic strains of cloned plants; (6) reestablishment of plants in selected ecosystems and natural areas via the above means; and (7) hybridization of selected species by means of protoplast culture.

LITERATURE CITED

Butenko, R. G. 1968. Plant tissue culture and plant morphogenesis. Trans. from Russian by Israel Program for Translation, Jerusalem. 291 p.

Cain, S. A. 1968. Natural area preservation: National urgency. BioScience 18:399-402.

Chen, C. H., and D. J. Holden. 1975. Cloning Lilium philadelphicum L. by tissue culture. Proc. S. D. Acad. Sci. 55:51-55.

Darnell, R. M. 1976. Natural area preservation: The US/IBP conservation of ecosystems program. BioScience 26:105-108.

Ellis, B. E. 1975. Propagation of selected native prairie plants by tissue culture. M.S. Thesis, So. Dak. State U., Brookings.

Gosnell, Mariana 1976. Please don't pick the butterworts. Nat. Wildlife 14:33.

Harlan, J. R. 1975. Our vanishing genetic resources. Science 188:618.

Holden, D. J., and J. T. Sorensen. 1972. The living antiques of the Couteau des Prairie. Prairie Nat. 4:61-64.

Humke, J. W. 1975. The preservation of natural diversity; A survey and recommendations. Final Rept., Prepared for the U.S. Dept. of the Int., by the Nature Conservancy, Contract No. CX001-5-0110.

Jacobson, E. T. 1975. The evaluation, selection and increase of prairie wildflowers for conservation beautification. In: M. K. Wali, ed. Prairie: A multiple view. p. 395-404.

Jenkin, R. E. 1975. Endangered plant species: A soluble ecological problem. The Nature Conservancy News 25:20.

Murashige, T. 1974. Plant propagation through tissue culture. Ann. Rev. Plant Physiol. 25:135-166.

Schumacker, Charles. ed. 1976. Potential list of endangered plant species in South Dakota. Preprint, South Dakota Endangered Plant Committee.

Sorensen, J. T., and D. J. Holden. 1974. Germination of native prairie forb seeds. J. Range Mgmt. 27:123-126.

Street, H. E. ed. 1974. Tissue culture and plant science. Academic Press, New York.

Stone, E. C. 1965. Preserving vegetation in parks and wilderness. Science. 150:1261-1267.

White, P. R. 1965. Plant tissue culture. McCutchan, Berkeley, Calif.

MAN'S EFFECT UPON A COLONY OF SISTRURUS C. CATENATUS (RAF.) IN NORTHEASTERN ILLINOIS (1834-1975)

Charles L. Bushey
Lake County Forest Preserve District
2000 North Milwaukee Road
Libertyville, Illinois 60048

ABSTRACT

The present range of a colony of Sistrurus c. catenatus in southeast Lake County, Illinois, was determined. A description of the colony's extent in 1834, before the habitat was modified by European man, and the range in 1939 and 1975, after extensive modification, are proposed. Changes in habitat and land use during this period (1834-1975), and the resulting effect upon the species, are discussed, along with the likely future of the colony. A common name is Massasauga, or prairie rattlesnake.

INTRODUCTION

A colony of Sistrurus c. catenatus (Raf.), the Eastern Massasauga Rattlesnake, has existed along and near the Des Plaines River in Lake and Cook Counties, Illinois, since before European settlement. This species spread across the prairie during the Pleistocene, in conjunction with available wetlands. Prior to settlement by Europeans, this habitat had already started to disappear in many areas (Klauber 1972). The reptile was at one time common throughout prairie areas (Wright 1940), but now is found in very scattered localities.

This paper describes the reduction of the Massasauga range in southeastern Lake County, Illinois, and presents reasons for that reduction. Probable distribution of the species prior to settlement in 1834 was determined for the study area. Distribution patterns were also mapped for 1939 and 1975. Both the 1939 and 1975 maps show a decline in range from the previous study period. These range declines are discussed in relation to vegetation changes caused by man's use of the land. A brief discussion is offered on the future of the species within the area.

METHODS

Lake county lies in the northeast corner of Illinois, adjacent to Lake Michigan. Topography of the study area is characteristic of the Wheaton Morainal Country, and is dominated by the Lake Border Morainic System (Larsen 1973). This system consists of five moraines that are separated much of their length by parallel valleys: the Des Plaines Valley, and the valleys of Chicago River tributaries. The Tinley Drift and the Tinley Moraine occupy part of the western section of the study area. The Tinley Moraine has a rough topography, similar in many respects to the Valparaiso Moraine, with many kames, eskers, and lakes (Willman 1971).

Drainage in much of the area is very poor, with many depressions and marshes (Paschke and Alexander 1970). The Des Plaines River drains the western part of the study area and part of the Park Ridge Moraine of the Lake Border Morainic System. The Des Plaines River Valley originally was drainage for glacial meltwaters, with sand, silt, and gravel in the valley (Larsen 1973).

The boundaries for the presettlement (1834) study area included all of Deerfield and Vernon Townships, Libertyville Township sections 13 through 36, and Shields Township sections 16 through 34. The area studied for the years 1939 and 1975 included the western half of sections 19, 30, 31 in Deerfield Township; and sections 25, 26, 35, and 36 and the southern half of sections 23, 24 in Vernon Township.

Several different methods were used to determine both the distribution of the Massasauga within the study area boundaries, and man's effects on the population of the snake. Methods used depend on the time period studied and the various reference materials which were available.

The year 1834 was chosen as the base year for the probable distribution of the Massasauga Rattlesnake in presettlement times; 1834 was the year the first European settler established a farm in southeastern Lake County (Halsey 1912). To determine the probable distribution of the rattlesnakes for this early date, information from several different sources were evaluated.

The Massasauga occupies particular areas of preferred habitat. Habitat descriptions of specimens collected from Lake County and the Chicago region have been made in several papers (Necker 1939, Schmidt and Necker 1935, Wright 1940, 1941). This information, combined with present rattlesnake habitat descriptions, indicated the species' preferred habitats. These preferred habitats were then matched to plant communities that existed during presettlement times, and to geological and drainage patterns.

A presettlement vegetation map for southeast Lake County (Fig. 1) was made with R. C. Moran (1978) and his study of the presettlement vegetation patterns for the entire county. Presettlement vegetation information for Lake county was obtained from the original Government Land Office survey records made by the 1840 surveyors. Microfilms of the survey field notes and witness tree data are available from the Recorder of Deeds Office, County Building, Waukegan, Illinois. Photostat copies of the original township plats were made available by the Lake County Highway Department in Libertyville, Illinois.

A search of historical references was made for early rattlesnake accounts by settlers. No written records confirmed locations, but a map showing homesteads established by 1845 indicates rattlesnakes in the prairie area southwest of the present location of the city of Deerfield, Illinois. A symbol showing a coiled rattlesnake was used in the map drawn in 1935 by James L. Hrale of Deerfield. The map was found several years ago when the Deerfield Library moved to a new building. It is not known how the library acquired the map, nor what sources of information Mr. Hrale used in drawing the map.

A map showing the range of the Massasauga in southeast Lake County during the year 1939 was determined from information in Wright (1940, 1941), and from conversations with residents familiar with the study area at that time. The land use and vegetation patterns were determined from aerial photographs flown on 31 July 1939. Both photographs were made available by the USDA-Soil Conservation Service Office in

Lake Zurich, Illinois.

A range map for the Massasauga in the study area for 1975 was determined largely from collection of live specimens. This was accomplished by repeated hiking of the habitat in the study area. The study area in Vernon and Deerfield Townships is approximately 10 km^2, bounded by Lake-Cook Road on the south, Saunders Road to the east, Milwaukee Avenue (U.S. 45, Ill. 21) on the west, and the southern boundary of the Village of Lincolnshire and Duffy Lane to the north.

Several other sources were also checked for records of Massasauga sightings in previous years. News accounts in local newspapers were considered acceptable if the snake was positively identified as either Massasauga or rattlesnake and an address for the specimen was included for site location. The Lake County Sheriff's Office in Waukegan, Illinois, and the Lake County Animal Warden in Wauconda, Illinois, were also consulted.

Land use and vegetation patterns for the study area during 1975 were determined from aerial photographs available from the Northeastern Illinois Planning Commission. Field investigations were used to further define the vegetation and land use pattern present at the time.

Conversations with long-term residents of the study area probably yielded the most information on the location and habitat associations of specimens from past years. Past and present land use were also discussed to help determine man's effects on the Massasauga.

Verification of species identification was obtained by studying preserved specimens at the Chicago Academy of Science, and the Chicago Field Museum of Natural History. When possible, the collection point of preserved specimens was obtained. The collection date of the preserved specimens determined the range map on which the snake specimen was marked.

RESULTS AND DISCUSSION

Vegetation patterns in Lake County (Fig. 1) were established for a period of time long enough to produce characteristic soil profiles in different plant communities (Moran 1978). The Eastern Massasauga during the same time period had become well established in the areas where the habitat was suitable for its survival.

Throughout its range, the preferred habitat of the rattlesnake appears to be moist prairies or grasslands, often near or in a forest ecotone. In Canada, specimens have been found in swamps, bogs, and meadows (Froom 1964). Atkinson and Netting (1927) reported that the Massasauga evidently followed a post-glacial tongue of prairie which extended into Pennsylvania from Ohio, along the Beaver River. Rattlesnake colonies became isolated in marshes as the prairie was succeeded by timber. Snakes were not found in areas which were never prairie. Seasonal changes in habitat also occurred, as snakes were found in grainfields or other high ground during the summer. In autumn they returned to the swamps and remained there until the next spring.

In Illinois, the Massasauga could have been considered common over the northern four-fifths of the state (Smith 1961). The snakes may now be a forest-edge species, but once were representative of a more extensive boreal herpetofauna. Specimens can now be found in wooded areas, with a preferred habitat of prairie grasses or old field with a heavy grass cover. Smith and Milton (1957) included the Massasauga in a group of reptiles and amphibians characteristic of the humid tall-grass prairies, essentially marsh or muck prairie. Most species within this group occurred on sand prairies, on the light soils of prairie outliers and on the heavier soils of the Wisconsin glacial till.

Prior to European settlement, there appear to have been two different areas occupied by the rattlesnakes in southeastern Lake County (Fig. 2), extending into the county from adjacent Cook County to the south. The colonies followed different routes of migration to reach their furthest extent within the study area. Very little contact, if any, probably existed between the colonies in Lake County, even though at some points less than two km separated the colonies.

One colony occupied low land along the west bank of the Des Plaines River and its tributaries that drained the mesic prairie to the west. The population of this colony was probably never very large because the available habitat was not extensive. The largest concentration of rattlesnakes in this colony would have occurred in the wet prairie area adjoining the drainage of Buffalo and Aptakisic Creeks. During this study live specimens were never found further than approximately eight hundred meters from low, moist areas. These habitats not only provided the optimum vegetation habitat for the snakes, but also served as hibernation sites in the fall and possibly breeding sites in the spring.

Marshes and potholes in the southwest portion of the study area provided a network of "stepping stones" that the Massasauga could use to extend its range into the region. When the distance between marshes and potholes grew and were filled by expanses of mesic prairie, lack of low, moist areas prevented expansion into much of the Indian Creek Basin, and into the northwest corner of the study area where mesic prairie dominated. In this latter area, distances often over 1.5 km between wet areas are usual, and no Eastern Massasauga specimens have even been reported from this former prairie area.

Another segment of this same colony occupying the west bank of the Des Plaines River crossed to portions of the east bank. Low areas along the river flood in late winter and early spring, and are usually dry during May through January. The snakes in this area were restricted in their movements, remained in the low prairie along the river bank, and did not range extensively into the mesic prairie. The west river bank in the NW 1/4, Sec. 26, T43N, R11E, rises in a sharp bank from the river's edge. The mesic prairie extended right up to the river's edge at this point and the lack of low, moist habitat appears to have effectively blocked further expansion up river.

Froom (1964) refers to a Massasauga found swimming in water; however, this seems to be the exception rather than the rule.

Some authors have made a point of mentioning

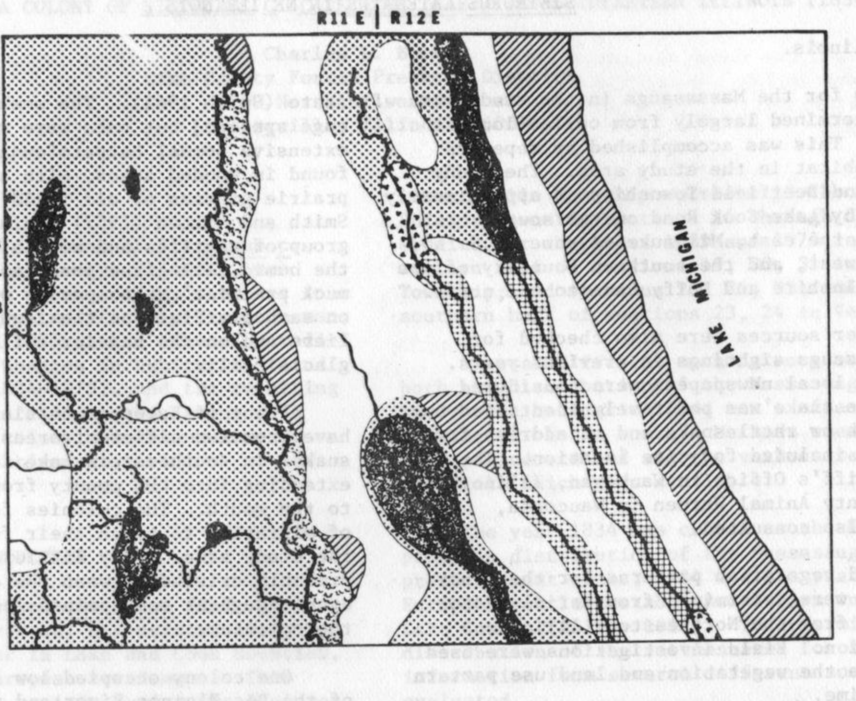
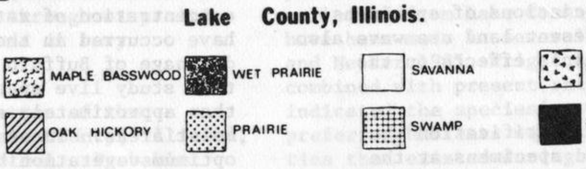


Figure 1. Presettlement Vegetation of Southeastern Lake County, Illinois.



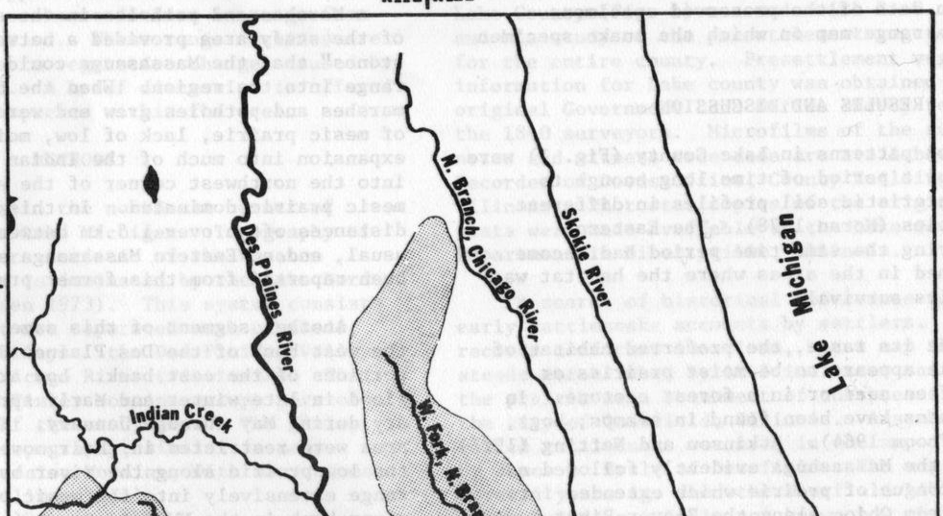


Figure 2. Range of Sistrurus c. catenatus in SE Lake Cty, Illinois (1834).

specimens seen in moist areas but not in standing water (Wright 1941; Wright and Wright 1957). During the summer, when the Des Plaines River is often less than a foot in depth and in some spots quite narrow, it is likely that individuals did cross the river, and these crossings did occur often enough to establish a small population of rattlesnakes along the east bank of the Des Plaines River. The snakes were extremely limited to habitat along the bank and low areas near the bank by a Acer saccharum-Tilia americana (sugar maple-basswood) forest occurring on the east bank.

A dense, mature forest is an effective natural barrier to the Massasauga in this area. Specimens have not been seen ranging further than 20 m into a heavily forested situation, but will frequent the edge. Snakes have been found to range further into a Quercus-Carya (oak-hickory) edge than a sugar maple-basswood forest, perhaps because of the heavy canopy layer of the latter, compared to the more open oak-hickory forest, which supports a good ground cover. The heavier shade in the sugar maple-basswood forest would reduce movement in an already slow-moving reptile.

The second colony of Eastern Massasauga rattlesnakes in southeastern Lake County was found in wet prairie, occurring primarily between the Park Ridge and Deerfield glacial moraines of the Lake Border Morainic System. This colony centered around the West Fork of the North Branch of the Chicago River (Fig. 2). The colony extended from the forests along the Des Plaines River to the west, north approximately 8 km into Lake County, and east to the North Branch of the Chicago River. The southern boundaries for both of the colonies was in Cook County, and at one time probably was an extension of the Massasauga population that developed in the wet prairie of the Chicago Lake Plain. Kennicolt (1855) considered the Massasauga a common species in Cook County.

Much of the land area between the Park Ridge and Deerfield Moraines is very poorly drained and subject to seasonal ponding. This perched water table occurs primarily in the spring of the year. Many areas remain moist the entire year, but shrink greatly in size. These wet depressions were the sites where the major concentrations of the Eastern Massasauga developed.

The presettlement vegetation of the area between the moraines was prairie, much of it wet prairie (Fig. 1). A savanna habitat occupied the rolling topography of the sides of the moraines. This plant community was composed of prairie plants as ground cover with scattered trees. Quercus macrocarpa was the most common species, with Quercus velutina and Quercus alba co-dominant tree species in this area (Moran 1978).

A good description of the different undisturbed habitats in the area occupied by the rattlesnakes was given in 1833 by Colbee C. Benton as he traveled through Lake County:

Thursday August 22

"Took a northwest direction from the lake and travelled about ten miles through rich land and very heavily timbered, about two miles through marshy land and some of the way almost impassable on account of the mud and mire. On our left was to be seen a large prairie as far as the eye could see. We kept in the woodland near the prairie and traveled about five miles farther (through rather poor land) where we found an Indian village. Passed across a fine rich prairie covered with a great variety of the most beautiful flowers, some on stalks higher than I could reach from my horse, . . . It was about four miles across this prairie and it is no doubt a continuation of the one I had before seen, as it extended to the south farther than I was able to see.

From this prairie it is about two miles through heavy timber land to the O'Plain River (or des Plaines) . . . forded the river (which was not very deep), and came out on a low prairie where the grass was higher than my head. Soon rose onto the dry prairie which was a grand one," (Benton 1957).

It should be noted the difficulty Benton had crossing the Skokie River and the North Branch of the Chicago River, which at that time were marshland. His crossing was in late August, the time of the year when evaportranspiration exceeds precipitation in northeastern Illinois (Sheaffer and Zeizel 1966), and therefore the easiest time for crossing. These marshes posed a major barrier to migration and range extension by the Massasauga.

In 1939, a hundred and five years after the first European settler, the vegetation and the range of the Eastern Massasauga in southeastern Lake County had changed considerably. The population and range of the rattlesnakes had been greatly reduced (Fig. 3). The introduction of the steel plow into Lake County resulted in the rapid conversion of prairie areas into cropland. The overturned soil was a habitat loss for the snakes as well as a loss of food sources. The plowed fields further prevented movement between wet depression areas and isolated pockets of the population. The smaller the isolated snake population sites, the more rapid was the decline. Draining of wet areas and channelization for additional agricultural lands resulted in further loss of habitat. Within isolated pockets, inbreeding may also have resulted in the decline of some populations of the snakes (Wright 1940).

A small population of snakes still occurred along the west bank of the Des Plaines River at this time. The population segment was restricted to a thin strip of habitat approximately 20-30 m in width along the river edge. These snakes were sometimes seen in late spring sunning themselves on the warm, freshly plowed soils. They never were reported far from the grassy edge dropping down toward the river (William Craig, personal comm.).

The Massasauga range and habitat was extensively modified in the former wet-mesic prairie and savanna habitats between the Park Ridge and Deerfield Moraines. Much of this prairie area was developed for agriculture by the settlers. Large areas of timber from both the savanna and forest communities were cut. While plowing destroyed habitat, timber cutting opened up new areas for the snakes. The cut-over sites were usually used to pasture livestock because the effort required to remove stumps for plowing was too great. Little new habitat was created for the snakes by cutting as compared to the

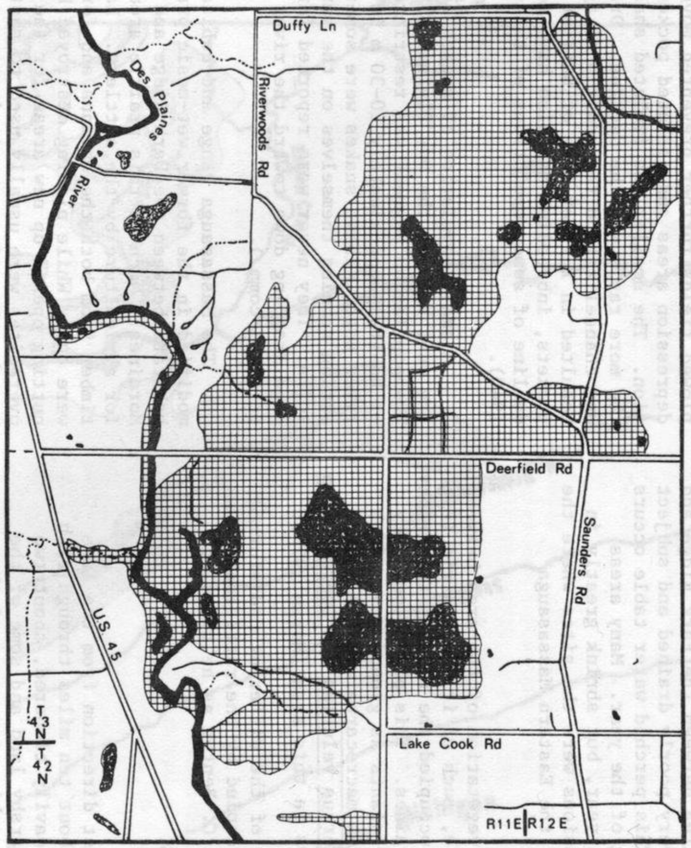


Figure 3. Range of Sistrurus c. catenatus in SE Lake Cty, Illinois (1939).

RANGE   MOIST DEPRESSION SITES

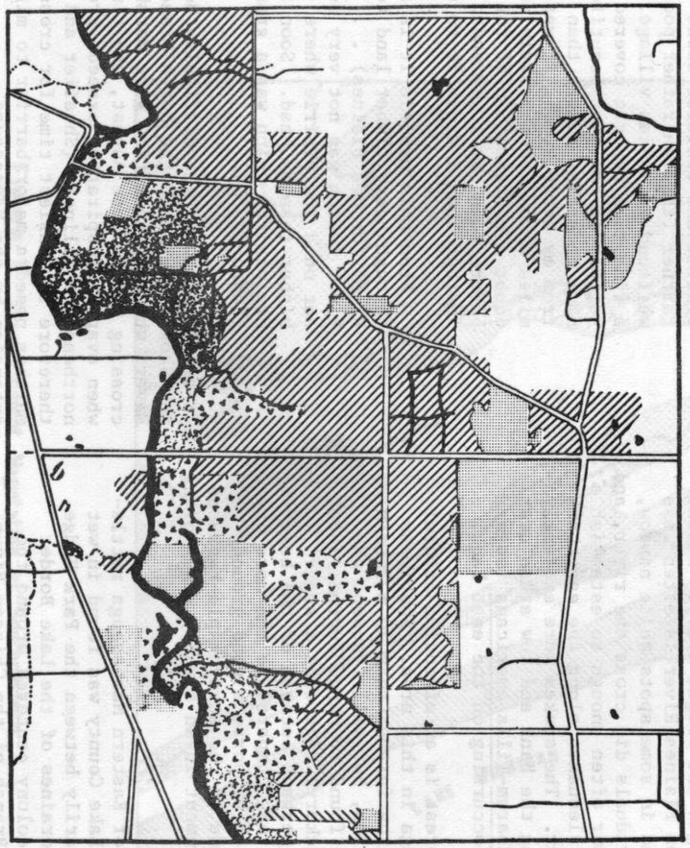


Figure 4. Vegetation Pattern of the Study Site (1939).

MAPLE - BASSWOOD   GRASSLAND   SUCCESSIONAL
OAK - HICKORY   CROPLAND   WATER

amount destroyed by plowing. The remaining population of the Massasauga Rattlesnake in southeastern Lake County is restricted to approximately 10 km^2 of the formerly forested area (Fig. 3) which was either used for pasture or allowed to grow into brush.

The early settlers, probably unknowingly, nearly destroyed the remaining population by either turning their pigs loose, or allowing many to escape from the surrounding farms. A large population of "wild boars" came to occupy the forested areas and edge in a very short time. Klauber (1972) mentions that hogs have been seen killing and eating rattlesnakes, which would cause a noticeable decrease in the Massasauga population levels. A decline in the local rattlesnake population was noticed by residents as the pig population increased. Later, "wild boar" hunts became a sport for many of the residents. They not only "enjoyed the hunt," but eliminated the potential pig hazard at the same time. The last "wild" pig killed was claimed by a Mr. Carland, a Road Commissioner from Deerfield, around 1890. Within a few years residents noticed a rapid increase in the number of rattlesnakes (George Herrmenn, personal comm.).

An increasing number of snakes, and favorable changes in habitat in the formerly forested areas, allowed the snakes to move into areas previously unoccupied by the species. Populations, which had decreased because of man's introduced predators and from changing habitat, were now slowly expanding. Contact was established between the snakes restricted to the east bank of the Des Plaines River and the colony of the West Fork of the North Branch of the Chicago River in areas cleared of timber to the river edge. This explains the unexpected appearance of rattlesnakes in some of the Cook County Forest Preserves in the summer of 1933 as mentioned by Wright (1941). This particular Forest Preserve, Dam #1, was pasture land with scattered trees left after the sugar maple forest was removed for lumber. A population segment existed on the west side of the river and was able to establish itself on the east bank and into the pasture. This population probably then merged with snakes expanding from the opposite direction.

The largest remaining concentration of rattlesnakes, at this time, was in an area studied by Wright (1941). The majority of his specimens were collected in an area that is representative of the seasonally perched water table of the morainic system. This former savanna area had earlier been cut for lumber but was growing back into a flat-oak woods, dominated by Quercus bicolor. The snake population here had remained relatively undisturbed until the construction of Deerfield and Portwine Roads through the area. During the construction, the crew killed approximately 40 snakes as they extended Deerfield Road through the open oak forest. No den site was discovered at the river as described by Wright (1941), nor were snakes seen in the sugar maple-basswood forest. Over 100 snakes were killed during the construction of Portwine Road through the flat-oak woods. A common sight after the road was finished, especially in the mornings, were road killed rattlesnakes. More snakes from this area were killed when the Vernon Ridge Country Club golf course to the east of the flat-oak woods was constructed (George Herrmenn, personal comm.).

Another site containing a large population occupied a former savanna habitat grown into an oak-hickory forest. In 1901, a lumber company purchased the area (NW 1/4, Sec. 25, T43N, R11E) and cleared it of timber. The land was then used for pasture, and up to 30 snakes a year were killed on the 4.9 ha tract. The site by 1939 had been converted to cornfields; an occasional snake was seen near the edges (George Herrmenn, personal comm.).

The same 4.9 ha tract by 1975 was no longer in cultivation, and was an old field habitat with many young trees. The rattlesnakes have moved back into the site and now this area contains the largest concentration of Massasaugas left in southeastern Lake County.

An area northeast of Riverwoods Road and south of Duffy Lane also contained a large number of Massasaugas. This site contained several low, wet areas in a habitat that in 1939 still maintained much of the appearance of a savanna. The population in this area was able to expand its range across the North Branch of the Chicago River when the marsh was channelized. By 1975, much of the area had been subdivided into homes and a large segment of the rattlesnake population had disappeared. The few that crossed the North Branch of the Chicago River were destroyed during construction of the Illinois Tollway (I-94).

The construction of large numbers of houses for people on the same sites occupied by the rattlesnakes is a recent occurrence. Prior to 1939, the study area was sparsely settled, most people living in towns or on farms in the former prairie. The few who did live in the area avoided the snakes as much as possible and killed the few they came across. The clearing of the forested areas and the forest edges for homes presented a unique problem. The newly-made open areas attracted the Massasauga. The home owners then killed the snakes because they were a potential hazard to children and pets. In the mid-1960's, housing in the area increased considerably. The wet depression sites studied by Wright (1941) were extensively drained for housing, as were other sites. This trend continues at a rapid pace and will continue for the forseeable future. As additional housing is built, habitat for the snakes will be lost.

The rattlesnake population on the west bank of the Des Plaines River in 1975 has been practically eliminated (Fig. 5). A few specimens are still found on private property north of Deerfield Road. Continued agricultural pressure, and the developing residential and commercial suburban pressure, has been enough to eliminate almost the entire colony.

Future survival for remaining populations of the Eastern Massasauga in southeastern Lake County does not appear likely. The population will meet increasingly with construction within the study area, reducing habitat, and with an increasing human population which is generally hostile toward the snakes. Small populations may continue in scattered locations for a number of year, but these populations will eventually die off due to lack of habitat, inbreeding, and increased human traffic. Favorable habitat will be reduced as the presently-occupied sites mature into forested habitat. The Massasauga can adapt to new areas if habitat is suitable, but increasing suburban pressure on the present population poses a situation in which the species, in all

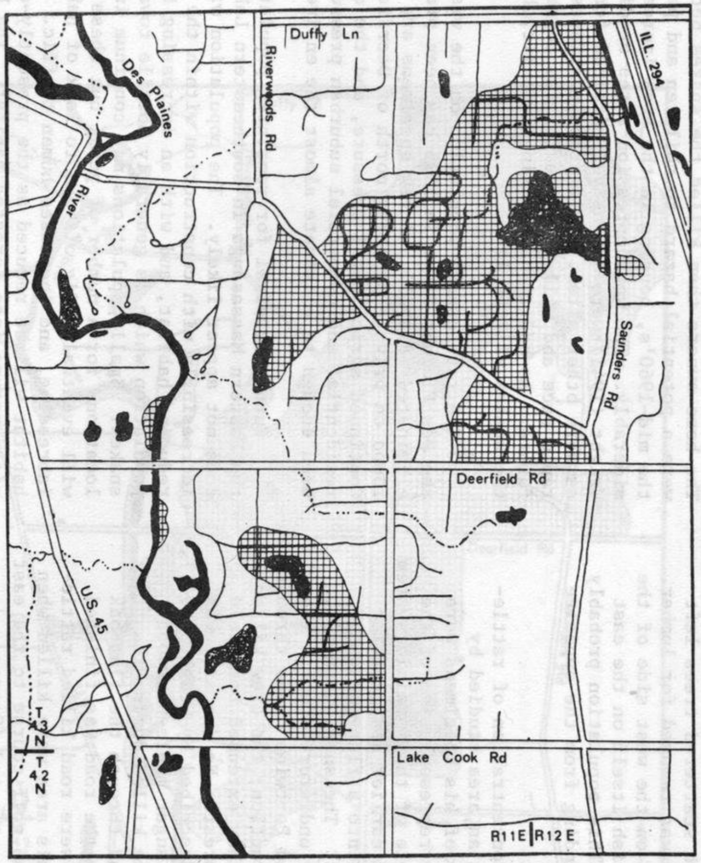


Figure 5. Range of <u>Sistrurus</u> <u>c.</u> <u>catenatus</u> in SE Lake Cty, Illinois (1975).

RANGE — MOIST DEPRESSION SITES

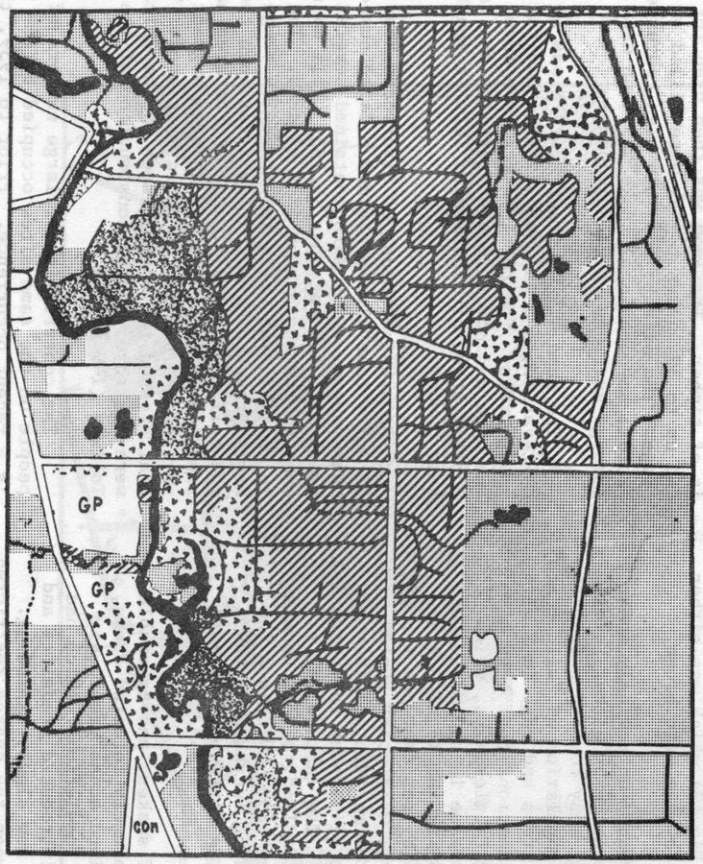


Figure 6. Vegetation Pattern of the Study Site (1975).

MAPLE-BASSWOOD — GRASSLAND — SUCCESSIONAL — OAK-HICKORY — CROPLAND — WATER — GP GRAVEL PIT — COM COMMERCIAL probability, cannot survive.

ACKNOWLEDGEMENTS

The author would like to thank Don Wheeler, William Craig, and George Herrmenn for their invaluable information and help on the history and habits of the Eastern Massasauga in southeast Lake County, Illinois. Also to Robbin Moran and his help with the presettlement vegetation section of this study. A special acknowledgement is expressed to Mr. Bernard of the Field Museum of Natural History, and Mr. George Iannarone of the Chicago Academy of Science, for allowing the author to obtain information on specimens within their agencies' collections.

LITERATURE CITED

Atkinson, D. A., and M. G. Netting. 1927. The distribution and habits of the massasauga. Bull. Antivenin Inst. Am. 1:40-44.

Benton, C. C. 1957. A visitor to Chicago in Indian days. The Caxton Club, Chicago. 121 p.

Froom, B. 1964. The massasauga rattlesnake. Can. Audobon 26:78-80.

Halsey, J. J. 1912. History of Lake County, Illinois. Harmegnies and Howel, Chicago. 879 p.

Kennicolt, R. 1855. Catalogue of animals observed in Cook County, Illinois. State Ag. Soc. Trans. for 1853-1854. 1:577-595.

Klauber, L. M. 1972. Rattlesnakes: Their habits, life histories, and influence on mankind. 2nd ed. Univ. Calif. Press, Berkeley. 2 vol.

Larsen, J. I. 1973. Geology for planning in Lake County, Illinois. Ill. State Geol. Sur. Circ. 481. 43 p.

Moran, R. C. 1978. Presettlement vegetation of Lake County, Illinois. These Proceedings.

Necker, W. L. 1939. Poisonous snakes of Illinois. Chicago Nat. 2:35-47.

Paschke, J. E., and J. D. Alexander. 1970. Soil survey of Lake County, Illinois. Ill. Agr. Exp. Sta. Soil Rept. 88. 82 p.

Schmidt, K. P., and W. L. Necker. 1935. Amphibians and reptiles of the Chicago region. Chicago Acad. Sci. Bull. 5:57-77.

Shaeffer, J. R., and A. J. Zeizel. 1966. The water resource in northeastern Illinois: Planning its use. Northeastern Ill. Planning Comm. Tech. Rept. 4. 182 p.

Smith, P. W. 1961. The amphibians and reptiles of Illinois. Ill. Nat. Hist. Surv. Bull. 28. 298 p.

Smith, P. W., and S. A. Milton. 1957. A distributional summary of the herpetofauna of Indiana and Illinois. Am. Midl. Nat. 58:341-351.

Willman, H. B. 1971. Summary of the geology of the Chicago area. Ill. State Geol. Surv. Circ. 460. 77 p.

Wright, A. H., and A. A. Wright. 1957. Handbook of snakes of the United States and Canada. Cornell Univ. Press, Ithaca. 2 vol.

Wright, B. A. 1940. Cephalic deformities in embryos of the massasauga rattlesnake. Trans. Ill. State Acad. Sci. 33:221-222.

Wright, B. A. 1941. Habit and habitat studies of the massasauga rattlesnake (Sistrurus catenatus catenatus Raf.) in northeastern Illinois. Am. Midl. Nat. 25:659-672.

NATIVE PRAIRIE GRASS PASTURES AS NESTING HABITAT FOR BOBWHITE QUAIL AND RING-NECKED PHEASANT

Ronnie R. George

Iowa Conservation Commission
Chariton, Iowa 50049

ABSTRACT

Artificially established native prairie grass pastures were evaluated as nesting habitat for bobwhite quail (Colinus virginianus), ring-necked pheasants (Phasianus colchicus), mourning doves (Zenaidura macroura), and a variety of songbirds during a 3-year study in southern Iowa. A total of 98.1 ha (241.2 acres) of native grass fields were intensively searched during this period. Average pheasant nesting densities of one nest established per 1.5 ha (3.6 acres) of switchgrass exceeded densities in nearby domestic hayfields. Nest success rates in prairie grass pastures were far better than those in hayfields since the warm-season pastures were not subjected to harvest during the peak reproductive period. If prairie grass pastures become accepted by livestock producers in the Midwest, well-managed pastures could provide habitat for many forms of wildlife.

INTRODUCTION

Wildlife research studies throughout the Midwest have shown that alfalfa (Medicago sativa) and red clover (Trifolium pratense) hayfields, particularly when in combination with smooth brome-grass (Bromus inermis), provide preferred nesting cover for ring-necked pheasants. However, large numbers of nests are destroyed and many hens are killed each year when these fields are harvested for hay during early to mid-June, the peak of the pheasant hatching season (Baskett 1947; Leedy 1949; Klonglan et al 1959; Joselyn and Tate 1972). This has proven to be a serious limiting factor for pheasant production in the Midwest. If another type of nesting cover could be developed, which would be both acceptable to hen pheasants and safe from early-season hay cutting, much of the nesting habitat problem could be solved.

Iowa Conservation Commission wildlife biologists took note during the late 1960's and early 1970's when USDA Soil Conservation Service (SCS) personnel in southern Iowa began to recommend the incorporation of warm-season native grasses such as switchgrass (Panicum virgatum), Indian grass (Sorghastrum nutans), and big bluestem (Andropogon gerardii) in livestock grazing programs. Native grass pastures were reported to produce high quality livestock forage during the hot summer months when cool-season grasses such as bluegrass (Poa pratensis), orchard-grass (Dactylus glomerata) and fescue (Festuca arundinacea) were dormant, thereby providing the private livestock producer with an economic incentive for establishing and managing these species (Betts 1972).

Native grass pastures seemed promising as pheasant nesting habitat because grazing or mowing below 20.3-25.4 cm (8 to 10 inches) of height was not recommended by the SCS (this should allow sufficient residual cover for nesting the following spring), and grazing or mowing were unlikely to occur before the majority of the pheasant nests had hatched in late June or early July. Prairie grass pastures might also provide nesting habitat for bobwhite quail since the bobwhite historically inhabited the forest-prairie edge (Rosene 1969:10).

METHODS

Pure stands of Blackwell switchgrass, Nebraska 54 Indian grass and Pawnee big bluestem were seeded with the aid of a special grassland drill on nine 2.0 to 4.9 ha (5 to 12 acre) test plots at the Rathbun Wildlife Area in south-central Iowa during May and June, 1973. Of the three species, switchgrass proved to be the easiest to establish. Plots were mowed in August 1973, and sprayed with Atrazine at the rate of 2.24 kg/ha (2 lbs/acre) during April of 1974 and 1976 to reduce weed competition. Several plots required reseeding and additional study plots on both public and private land were added in subsequent years.

A variety of treatments were applied to study plots in order to simulate private management of warm-season pastures. Treatments included: hay mowing in July, grazing during July and August, and seed harvest in September. Other plots were left undisturbed to provide maximum residual cover the following spring.

Grass samples were collected during early July to determine quality and quantity of available livestock forage. Samples were clipped at a height of 20.3 cm (8 inches), air dried, weighed, and analyzed for crude protein.

Intensive nest searching of the pure stands of switchgrass, Indian grass, and big bluestem began in 1974 and continued through 1976. In addition, mixed stands of these three species and an actual prairie remnant consisting of an almost pure stand of little bluestem (Andropogon scoparius) were included in the nesting study. Privately owned alfalfa and orchard-grass hay meadows in the immediate vicinity of the study area were also searched to provide a direct comparison of nest density and nest success in cool-season hayfields with those of warm-season prairie grass pastures. Most fields were searched twice, once in June and once in July. Nest searching was accomplished by a crew walking abreast and parting the vegetation with a stick. Active nests were marked and revisited until the fate of the nest was determined. Fields scheduled for hay cutting were usually searched only once, immediately after the hay was raked or baled.

RESULTS AND DISCUSSION

A total of 98.1 ha (241.2 acres) of native grasses were searched during the course of this study, and a total of 137 nests including 57 pheasant, 5 quail, 5 dove, and 70 songbird nests were discovered (Table 1).

Pheasant nesting densities were highest in mixed native grass, little bluestem, and switchgrass (Table 2). Pheasant nest success was greatest in mixed native grass and switchgrass. When pheasant nesting densities in 56.2 ha (138.1 acres) of switchgrass are compared with nesting in 26.9 ha (66.2 acres) of privately-owned alfalfa/orchard-grass (Table 3), densities of 0.68 nest per ha in switchgrass exceeded densities in alfalfa/orchard-grass (0.41 nests per ha). In addition, 0.28 nests per ha in switchgrass greatly surpassed the nesting success we found in cool-season hay meadows where mowing operations destroyed 11 nests and killed 8 hens in 26.9 ha (66.2 acres) of privately-

Table 1. Nests discovered in native prairie grasses on the Rathbun Wildlife Area from 1974 through 1976.

Grass species	Hectares searched	Pheasant E[a]	Pheasant S[b]	Quail E	Quail S	Doves E	Doves S	Songbirds E	Songbirds S
1974									
Switchgrass	16.2	3	2	0	0	0	0	4	2
Little bluestem	2.9	0	0	0	0	0	0	0	0
Total	19.0	3	2	0	0	0	0	4	2
1975									
Switchgrass	20.0	15	7	2	0	1	0	12	5
Little bluestem	2.9	3	1	2	2	0	0	2	1
Big bluestem	4.9	1	1	0	0	0	0	8	4
Indian grass	6.9	2	1	0	0	2	2	12	6
Total	34.7	21	10	4	2	3	2	34	16
1976									
Switchgrass	20.0	20	7	0	0	2	1	9	1
Little bluestem	2.9	3	1	0	0	0	0	3	0
Big bluestem	4.9	0	0	0	0	0	0	7	2
Indian grass	13.0	6	2	1	1	0	0	7	0
Mixed native	3.6	4	3	0	0	0	0	1	0
Total	44.4	33	12	1	1	2	1	27	3
3-year total	98.1	57	24	5	3	5	3	70	21

[a]Established nest = nest bowl with two or more eggs (one or more for songbirds).

[b]Successful nest = one or more hatched young (fledged for doves and songbirds).

Table 2. Pheasant nests discovered in native prairie grasses during a 3-year study on the Rathbun Wildlife Area.

Grass species	Hectares searched	Nests established[a]	Established nest/ha	Nests successful[b]	Successful nest/ha
Switchgrass	56.2	38	0.68	16	0.28
Little bluestem	8.7	6	0.69	2	0.23
Big bluestem	9.8	1	0.10	1	0.10
Indian grass	20.0	8	0.40	3	0.15
Mixed native grass	3.6	4	1.11	3	0.83
Total	98.1	57	0.58	25	0.25

[a]Established nest = nest bowl with two or more eggs.

[b]Successful nest = one or more hatched young.

Table 3. Pheasant nests discovered in privately-owned hayfields in the vicinity of the Rathbun Wildlife Area in 1976.

Plant species	Hectares searched	Nests established[a]	Established nests/ha	Nests successful
Alfalfa/orchard-grass	26.9	11	0.41	0[b]

[a]Established nest = nest bowl with two or more eggs.

[b]All nests destroyed by hay mowing (8 hens killed).

owned alfalfa/orchard-grass. Switchgrass was especially important as nesting cover since stems from the previous year remain standing throughout the winter and provide residual nesting cover in the spring.

Quail nesting densities and nest success (0.23 nests per ha) were greatest in little bluestem. For mourning doves, the greatest nesting densities and nest success (0.1 nest per ha) occurred in Indian grass (possibly as a result of a greater amount of bare ground between clumps). Songbird nesting densities (1.43 nests per ha) were highest in big bluestem. Common nesters identified in this study included red-winged blackbirds (*Agelaius phoeniceus*), eastern meadowlarks (*Sturnella magna*), dickcissels (*Spiza americana*), yellow-throats (*Geothlypis trichas*), and field sparrows (*Spizella pusilla*). Skinner (1975) reported that a scattering of forbs in grassland communities greatly enhanced dickcissel and red-winged blackbird nesting densities. We also noted evidence of this relationship.

Mean crude protein values were 5.36% for switchgrass, 5.94% for Indian grass, 6.03% for big bluestem, and 5.88% for little bluestem. When compared with potential crude protein values of 16-20% for alfalfa in the late bud or early bloom stages, these crude protein values are not very impressive. However, none of these samples were collected in fertilized fields, and a lack of applied nitrogen plus over-maturity could certainly contribute to low crude protein values (Riedl, personal communication). Forage yields calculated at 286.0 g/m^2 (1.06 tons per acre) for switchgrass, 308.7 (1.15) for Indian grass, 244.5 (0.91) for big bluestem and 102.2 (0.38) for little bluestem are substantially less than those reported from fertilized fields in Iowa, Nebraska, and Missouri (Schaller 1973). The addition of nitrogen fertilizer should improve these low yields.

Switchgrass will probably remain one of the most desirable warm-season grasses since it is easy to manage and can be established with an ordinary grain drill or end-gate seeder. If it becomes widely accepted as an alternative to cool-season pastures and if it is managed in accordance with current SCS recommendations, switchgrass should provide suitable nesting cover for a variety of wildlife.

LITERATURE CITED

Baskett, T. S. 1947. Nesting and production of the ring-necked pheasant in north-central Iowa. Ecol. Monogr. 17:1-30.

Betts, L. 1972. Pasture that lasts all summer. SCS reprint from Wallace's Farmer - Feb. 12. 1 p.

Joselyn, G. B., and G. I. Tate. 1972. Practical aspects of managing roadside cover for nesting pheasants. J. Wildl. Mgmt. 36:1-11.

Klonglan, E. D., R. L. Robbins, and B. L. Ridley. 1959. Evaluation of effectiveness of pheasant flushing bars in Iowa hayfields. Proc. Iowa Acad. Sci. 66:534-552.

Leedy, D. L. 1949. Ohio pheasant nesting surveys based on farmer interviews. J. Wildl. Mgmt. 13:274-286.

Rosene, W. 1969. The bobwhite quail, its life and management. Rutgers Univ. Press. New Brunswick, New Jersey. 418 p.

Schaller, F. W. 1973. Warm-season grasses for pasture. Coop. Ext. Ser., Iowa State Univ. Ames. 4 pp.

Skinner, R. M. 1975. Grassland use patterns and prairie bird populations in Missouri. in: M. K. Wali (ed.). Prairie: A multiple view. Univ. N.D. Press, Grand Forks. 171-180.

BIRD HABITAT-WOODY PLANT RELATIONS ON MISSOURI LIMESTONE GLADES

George E. Probasco

Associate Research Wildlife Biologist
North Central Forest Experiment Station
Forest Service, U.S. Department of Agriculture
Columbia, Missouri (field office maintained in cooperation with
the University of Missouri Agricultural Experiment Station)

ABSTRACT

A 3(3) nested design with three levels of woody plant cover (light, moderate, and heavy), each containing three levels of eastern redcedar cover (light, moderate, and heavy), was used to test for associations between bird populations and selected vegetation conditions. Areas low in woody plant cover were low in bird numbers, species numbers, and diversity. Moderate levels of woody plant cover received greater use, while use in the heavy woody cover areas varied.

INTRODUCTION

The Missouri limestone glades are openings in the oak-hickory forest of south-central Missouri. Little bluestem (Andropogon scoparius) commonly dominates the areas; however, woody species such as smoke tree (Cotinus obovatus) and eastern redcedar (Juniperus virginiana) can become important components, and at times will dominate. Invading woody plants are considered a threat to the integrity of the glade community. Plant-animal relations for the glades are not well understood and the consequences for glade maintenance efforts are unpredictable. I conducted a study to determine the relations between bird numbers and bird species numbers with the various cover types that occur on the glades. I also wanted to find out the bird species that were associated with the cover types.

There are 202,350 ha (500,000 acres) of glades scattered through the Ozarks of southern Missouri; approximately 28,325 ha (70,000 acres) occur on the Mark Twain National Forest in Missouri. North American distribution of glades is from middle Tennessee to southern Missouri, then north along the Mississippi River to Wisconsin. Glades generally have sloping topography because they usually occur in mid-slope areas with forest cover both above and below. Occasionally a glade will cover the top of a ridge and here the topography will be nearly level.

Depth of the dolomitic limestone soils is variable. Rock outcrops occur regularly on the glades and give the landscape a banded or terraced appearance. Soils are deepest immediately below these outcrops and thinnest just above them. Trees and larger grasses such as big bluestem (Andropogon gerardii) are associated with these deeper soil pockets. Although these soils are thin, they are fertile.

Plant species associated with the glades are the grasses: little bluestem, big bluestem, Indian grass (Sorghastrum nutans), switch grass (Panicum virgatum), prairie dropseed (Sporobolus heterolepis), side oats grama (Bouteloua curtipendula), and on extremely thin soil areas, bald grasses (Sporobolus neglectus and S. vaginiflorus). Some of the characteristic forbs are blue-eyed grass (Sisyrinchium campestre), beard-tongue (Penstemon tubaeflorus), purple prairie clover (Petalostemum purpureum), prairie dock (Silphium terebinthinaceum), and wild blue larkspur (Delphinium carolinianum). Some of the less common forbs are rose gentien (Sabatia angularis), fame flower (Talinum calycinum), agave (Agave virginica), nemastylis (Nemastylis nuttallii), and purple penstemon (Penstemon cobaea var. purpureus), a threatened species. Common woody species are eastern redcedar, smoke tree, chittim-wood (Bumelia lanuginosa), ash (Fraxinus spp.), chinquapin oak (Quercus muehlenbergii), sugar maple (Acer saccharum), and dogwood (Cornus florida).

The glades are also habitat for some rare and unique animal species. Several southern or southwestern species reach their northern or northeastern range limits in the Ozark glades. Some of these are the tarantula (Dugesiella hentzi), collared lizard (Crotaphytus collaris), roadrunner (Geococcyx californianus), and Bachman's sparrow (Aimophilia aestivalis), a bird listed by the State of Missouri as rare.

METHODS

The question whether the glades in general are being invaded by woody plant species, especially eastern redcedar, remains unanswered; however, a range or gradient of woody plant cover conditions exists. Study plots ranged from glades that were nearly devoid of woody vegetation to areas that apparently had been glades but were now nearly covered by woody vegetation. Woody areas with residual prairie species plus the characteristic thin soils and rocky outcrops were judged to be former open glades.

A 3(3) nested design with three levels of woody plant cover (light--0 to 33 percent, moderate--34 to 66 percent, and heavy--67 to 100 percent) each containing three levels of eastern redcedar cover (light--0 to 33 percent, moderate--34 to 66 percent, and heavy--67 to 100 percent), was used to study associations between bird populations and the woody plant cover gradient. Figure 1 illustrates the relation between woody plant cover and redcedar cover. This gave a total of nine cover types.

At least 4 0.1 ha plots were established in each cover type. Data on bird activity and frequency were obtained in June using 30-minute observation frames, each divided into six 5-minute time intervals. Three or four plots were sampled each day between one-half-hour before sunrise to 10 AM. Sampling times were altered so that no plot was sampled at the same time.

RESULTS AND DISCUSSION

Most bird activity occurred in the moderate woody plant cover (Table 1). Activity in the heavy woody cover was slightly less--12 fewer birds and 1 less species. Total bird numbers for the light woody plant cover type were similar to the other two types, but species numbers were lower, 6 less than the moderate cover and 5 less than the heavy cover.

Bird diversity indices ($H' = \Sigma P_i \log P_i$; Margalef 1958) calculated for these three types were the same for moderate and heavy cover types, and the light cover type was only slightly less, indicating little differ-

Table 2. Observation numbers, species numbers, and diversity indices for the eastern redcedar cover subtypes.

	Total woody plant cover								
	Light			Moderate			Heavy		
	Redcedar cover								
	Light	Moderate	Heavy	Light	Moderate	Heavy	Light	Moderate	Heavy
Bird numbers	9	20	15	21	17	17	15	8	20
Species numbers	5	5	6	10	8	8	8	5	8
Diversity index	1.31	1.39	1.69	2.02	1.72	1.34	1.86	1.49	1.77

Table 1. Bird numbers, bird species numbers, and diversity indices for total woody plant cover.

	Total woody plant cover		
	Light	Moderate	Heavy
Bird numbers	44	55	43
Bird species numbers	10	16	15
Diversity index	2.5	2.8	2.8

ence in bird diversity among the three woody plant cover types.

Bird activity was more variable among the eastern redcedar cover subtypes (Table 2). For the light woody cover type, the most birds occurred in the moderate redcedar subtype, while the least number of birds occurred in the light redcedar subtype. Both the light and moderate subtypes contained one less species than the heavy redcedar subtype. This caused the heavy redcedar subtype to have a higher diversity index than either the light or moderate subtypes.

In the moderate woody cover type bird activity decreased as redcedar increased. The moderate-light subtype had the highest number of birds, the most species, and the highest diversity index of all nine subtypes. Bird numbers for both moderate-moderate and moderate-heavy subtypes were four less than the moderate-light subtype. Species numbers declined by two for the moderate-moderate subtype and by four for the moderate-heavy subtype. There were corresponding decreases in the diversity indices. The moderate-heavy was similar to the light-light and light-moderate. The implication is that additional redcedar in the moderate woody cover type decreases total bird numbers and species numbers.

Activity in the heavy woody cover type was mixed. The heavy-light and heavy-heavy redcedar subtypes both had the same number of species but the heavy-light subtype had five fewer observations. The heavy-moderate subtype had the fewest birds and species.

Table 3. Percent frequency of occurrence for characteristic species in light, moderate, and heavy woody plant cover types

	Light	Moderate	Heavy
Brown-headed cowbird	7	6	10
Field sparrow	12	20	1
Prairie warbler	8	14	1
Bachman's sparrow	2	0	0
Blue-gray gnatcatcher	0	8	9
Tufted titmouse	0	1	7
Black and white warbler	0	1	7

Frequency of occurrence (Table 3) for some of the characteristic bird species occurring in each of the woody plant cover types show important species composition differences. The field sparrow, prairie warbler, and Bachman's sparrow predominate in the light woody cover type. The field sparrow and prairie warbler continue to be important in the moderate woody cover type, but Bachman's sparrow does not. Bachman's sparrow appears to be restricted to the light woody type. The blue-gray gnatcatcher becomes important in the moderate cover type. In the heavy cover type the field sparrow and prairie warbler occur very infrequently. The blue-gray gnatcatcher remains an important species and two other species increase in importance, the tufted titmouse and the black and white warbler. The brown-headed cowbird is an important component in all the cover types.

The addition of some woody plant cover to the prairie vegetation generally increases bird numbers, bird species, and diversity until a moderate woody plant cover type with light redcedar cover is attained. Additional redcedar cover reduces bird numbers, bird species, and diversity within the moderate woody cover type. Bird numbers, species, and diversity are variable in the heavy woody cover type. The characteristic bird species occurring in the heavy cover type are generally considered forest species, indicating that this cover type may be a forest community rather than a glade community.

LITERATURE CITED

Margalef, D. R. 1958. Information theory in ecology. Gen. Syst. 3:36-71.

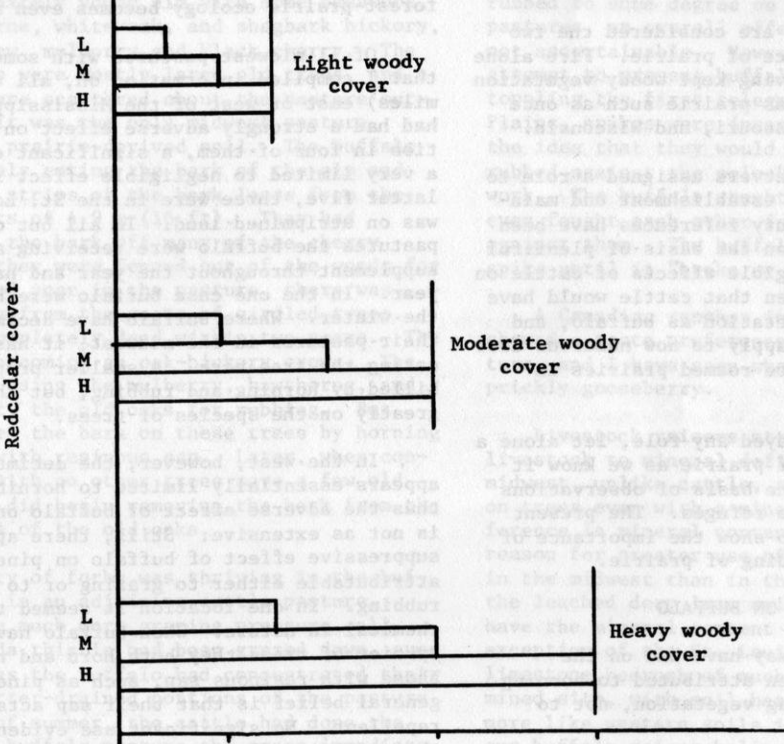


Figure 1.--The relationship between woody cover and redcedar cover

BUFFALO AND PRAIRIE ECOLOGY

Tom Edwards
Box 364
Washburn, Illinois 61570

ABSTRACT

Moisture levels and fire are generally credited with having kept woody vegetation from overwhelming prairie. That the American buffalo could have tipped the competitive balance one way or the other has been only scantily suggested by pioneers, and has since been largely discounted. However, it has been discounted mainly on the basis of the effects of cattle grazing and also on the basis of observations of buffalo in wildlife refuges of the far West. This discussion attempts to show the importance of buffalo and other large herbivores, particularly elk, in the establishment and maintenance of the historical prairie.

INTRODUCTION

Moisture levels and fire are considered the two factors governing the existence of prairie. Fire alone is generally credited with having kept woody vegetation from overwhelming the tallgrass prairie such as once existed in Illinois, Iowa, Missouri, and Wisconsin.

Though a few pioneer observers assigned a role to buffalo, elk, and deer in the establishment and maintenance of prairie, these scanty references have been discounted, evidently mainly on the basis of plentiful examples of negative or negligible effects of cattle on prairie. Assumptions have been that cattle would have about the same effects on vegetation as buffalo, and that the same parallel would apply to now numerous deer as opposed to the elk that once roamed prairies in large numbers.

That buffalo may have played any role, let alone a vital one, in the existence of prairie as we know it has also been discounted on the basis of observations of buffalo in western wildlife refuges. The present observations are an attempt to show the importance of buffalo in any full understanding of prairie.

OBSERVATIONS ON BUFFALO

Whatever effect buffalo may have had on the forest-prairie balance has been attributed to horning and rubbing trees and trampling vegetation, not to grazing (Roe 1972).

But I have found substantial evidence that: (1) buffalo have a much greater effect on woody vegetation than cattle; (2) that this adverse effect is likely to be considerably greater in the midwest than in the west and is also probably greater in the west than has been thought, and (3) in the midwest this effect is primarily due to grazing rather than rubbing and trampling. Therefore, buffalo may have tipped the competitive balance in favor of prairie over forest.

Buffalo and other large herbivores may have been a significant factor in the balance between forbs and the more dominant grasses of prairie, something fire is also thought to have been responsible for. This is because buffalo evidently make little use of forbs in their diet. In the pastures I have observed, they graze in the spring and summer almost exclusively on grass, including one pasture that was predominately forbs and alfalfa. Records of stomach contents of buffalo at Yellowstone National Park indicate that forbs comprise only about 2 percent of their diet, about 90 percent of which was phlox and cinquefoil (Meagher 1973). Sedges and rushes comprised 61 percent and grasses 35 percent of their diet.

Buffalo also have considerably different effects on different species of trees, virtually ignoring some while literally ravaging others. In the midwest the two species they leave alone are oak and hickory, and it was oak-hickory groves that dotted the midwest prairie. Given a choice, they will select other species for horning and/or rubbing, and still others for eating the bark.

When it is considered that elk were as numerous, and probably more numerous than buffalo in the midwest, the possible effect of large native herbivores on forest-prairie ecology becomes even more impressive.

Of 11 midwest pastures with some woody vegetation that I compiled information on, all within 320 km (200 miles) east or west of the Mississippi River, buffalo had had a strongly adverse effect on the woody vegetation in four of them, a significant effect in two, and a very limited to negligible effect in five. Of the latter five, three were in the St. Louis area and one was on stripmined land. In all but one of the 11 pastures the buffalo were receiving a mineral protein supplement throughout the year and hay much of the year. In the one case buffalo were being given corn in the winter. Where buffalo have decimated trees in their pastures in the midwest, it has mainly been by eating the tree bark. A smaller proportion of trees is killed by horning and rubbing, but the ratio depends greatly on the species of trees.

In the west, however, the decimation of trees appears essentially limited to horning and rubbing, thus the adverse effect of buffalo on woody vegetation is not as extensive. Still, there appears to be some suppressive effect of buffalo on pines in the west not attributable either to grazing or to horning and rubbing. In one location it seemed to be almost chemical in nature. When buffalo have a choice, the species of trees they both horn and rub against are those with resinous sap, such as pine and cherry. The general belief is that their sap acts as an insect repellent. No significant use evidently is made of these species for eating. The horning and rubbing process eventually girdles the tree. Buffalo will continue to visit the same wound on a tree, and expand on it, as long as it continues to ooze sap.

Some species are used only for rubbing, which normally doesn't seem to break the bark. Still other species of trees are selected by buffalo for feeding on bark. Definite preferences exist in individual pastures, but because the species present differed so greatly from pasture to pasture, overall preferences were not ascertainable. Species from which buffalo were observed to have eaten bark are basswood, elm, maple, cottonwood, apple, white cedar, catalpa, and walnut.

When I observed them in a large pasture at Traverse City, Michigan, buffalo were essentially eating the bark of only one species, white cedar (<u>Thuja occidentalis</u>). However, the owner reported that in the several years they had been in the pasture they had wiped out a "cedar swamp woods" growing within the pasture. A fence exclosed one portion of the woods. Inside the fence with the buffalo were only a few elderberry bushes and white cedar stumps. Immediately on the other side were thriving white cedar, willow, dogwood, elm, sumac, balsam fir, and elderberry. Cattails were also evident only outside the fence. There was no invasion of trees or shrubs in the pasture, though such invasion is common in northern Michigan. At the time of the observation in July 1975, there had been relatively little grazing of the grass in the low areas, and one swampy area was virtually untouched. Forbs were little used, if at all, and the owner said the buffalo made little use of alfalfa when he turned them out into a grass-alfalfa hay field.

At the National Laboratory at Batavia, Illinois, a herd that started with 15 buffalo had girdled in less than a year, about 80 percent of 600 trees in a 1 ha grove within a prairie-soil pasture of about 36 ha (90 acres). But they had left virtually untouched the oaks and hickories, save for a few saplings. The grove was predominately young elm with some basswood, box elder, hawthorne, white oak, and shagbark hickory, and, in a fence row, mulberry and black cherry. The oaks and hickories were mostly large old trees, and a number of these were scattered about the pasture outside the grove. It was the only midwest pasture observed that had prairie-derived soil. The buffalo had been extensively eating the bark of the elm and basswood, pulling strips of the bark loose from the trees up to heights of 4.9 m (16 ft). They had horned and rubbed the bark off many of the cherry trees. Although they were fenced out of the woods for much of their third year in the pasture, there was little resprouting from the roots of girdled trees. Almost all were completely dead within two years. The grove is rapidly becoming an oak-hickory grove. The buffalo were also using the mulberry, hawthorne, and to a lesser extent, the old oaks for rubbing. But they had not broken the bark on these trees by horning as they do trees with resinous sap. Later, when confined to a field with no other trees save a few old oaks, the buffalo did begin removing the bark from the roots at the bases of the old oaks.

A wide variety of forbs was thriving in the buffalo pasture, but in an adjoining cattle pasture, which did not have much more grazing pressure, all forbs except Canada thistle had been grazed down, even smartweed. Whereas the buffalo had concentrated their grazing in the better-drained portions of the pasture until the middle of summer, the cattle had done the opposite. In the buffalo pasture the grass immediately under the oaks and hickories had been left largely ungrazed through July 1974, and the pattern of ungrazed grass distinctly outlined the crowns of the trees. However, in August the buffalo showed a preference for this grass, and the outlines of the crowns became as distinctly etched by shorter grass as they had been by longer grass a month earlier.

At Custer State Park, South Dakota, where only a woven wire fence separated a buffalo grazing area from a cattle grazing area, and where the habitat was otherwise virtually identical on both sides of the fence, ponderosa pines were heavily invading the cattle pasture. But in the buffalo area, though there were plenty of seed sources, there was virtually no new invasion of pine, and the buffalo were gradually eliminating the old clusters of ponderosa pine through horning and rubbing. Leadplant was conspicuous on the buffalo side, but not evident on the cattle side.

At Custer Park the buffalo were observed to move rapidly through woodlands to get to open grazing areas on the other side, and otherwise stayed in the open almost continuously. Where they graze there is continual decimation of the ponderosa pine forests along their outer edges, and of course, of any trees within the open areas. However, areas of Custer Park where the buffalo do little or no grazing are rife with woody invasion.

In a survey of buffalo ranchers I conducted through Buffalo magazine, most said that buffalo browse on woody shrubs. Though I have not had much opportunity to observe before and after evidence of this, the buffalo pastures I have visited have been remarkably free of woody shrubs.

Two buffalo raisers noted that their animals have rubbed their heads and horns so vigorously against pine seedlings that they worked them out of the ground. This has also been observed in Yellowstone National Park, and it seems to be a behavior associated only with the pine family. Though they have rubbed to some degree on thorn trees in two midwestern pastures, an overall effect on thorny vegetation was not ascertainable. However, it is noted that, in an attempt to prevent buffalo from rubbing against and toppling the first telegraph poles across the Great Plains, spikes were inserted around the poles, "with the idea that they would wound the buffalo as they rubbed against the poles" (Dary 1974). It did not work. The buffalo sought out the spiked poles and even fought each other for the privilege of rubbing against them. The buffalo would scratch against a spike until it "broke or the pole came down."

A Canadian rancher informed me that his buffalo showed a taste preference for wild rose in his pasture, and I have seen where they have eaten the very prickly gooseberry.

Livestock raisers attribute the eating of bark by livestock to mineral deficiencies, but buffalo in the midwest, unlike cattle, are liable to keep on gnawing on trees even with a mineral food supplement. A difference in mineral content of soils is a possible reason for greater use of woody vegetation by buffalo in the midwest than in the west. Grasses growing in the leached deep loam soils of the midwest may not have the mineral content the animals need. The exception of the St. Louis pastures may be due to the limestone bedrock of much of that area. The strip-mined site, with soil heaved from deep down, may be more like western soils in mineral content. However, one buffalo raiser believes that bark provides roughage buffalo need. And there may be a significant difference in the roughage factor of western and midwestern range vegetation. Of interest is that buffalo in both the west and midwest have been observed licking bare soil.

A corollary to the effect of the American bison on woody vegetation is that the European bison, the wisent, is a browser, making extensive use of woody vegetation.

CONCLUSIONS

From the evidence on hand it seems quite reasonable that buffalo have heavy impacts on woody vegetation under some environmental conditions, and could possibly have played, along with elk and other large herbivores, a vital role in the existence of prairie, and in maintaining openings in woodlands. They also may have played an important role in the distribution of the pine family in the midwest, which in northern Illinois occurred in only small relic stands. All my observations have been of buffalo that, besides being confined, had through supplemental feeding all they wanted to eat. Picture, though, herds of wild buffalo that have had to root through snow for months to obtain nutritionally deficient old and dead grass, or if there were as much fire as now thought, not grass at all. Think of the ravenous hunger in the winter that probably plagued buffalo, and of what the cambium layers of trees and the branches of shrubs would have meant to them, particularly late in the winter and early spring when the sap was rising. Indeed, even the Indians stripped the bark from slippery elm in such periods and chopped down cottonwoods for their horses. In one recorded instance a group of buffalo came down out of the mountains in Pennsylvania in the dead of winter, trampled three cattle to death in rushing to a farmer's haystack, toppled his log cabin, and were found a few days later still too weak from hunger to run from hunters. Think of the massive herds of buffalo in the west that crumbled riverbanks and filled ravines with their bodies when they stampeded, and actually drank rivers dry.

Over thousands of years buffalo, plus elk, must have had a tremendous botanical impact, not only by their continuous feeding, thrashing, trampling, and tearing of vegetation, but also by their selective use of vegetation and seasonal variations in grazing. This may be a third factor crucial to the establishment and maintenance of the historical prairie.

LITERATURE CITED

Dary, David. 1974. The buffalo book. Swallow Press, Chicago.

Meagher, Margaret M. 1973. The bison of Yellowstone National Park. Washington, U.S. National Park Service, Scientific Monogr. Ser. No. 1. 161 pp.

Roe, F. G. L972. The North American buffalo. 2nd ed. Univ. Toronto Press, Ontario. 911 pp.

Editors note: We have allowed considerable freedom in this article regarding the author's opinions on the effects of bison on prairie and forest vegetation. We recognize the scant documentation of his observations and the uniqueness of his opinions, not because we want to encourage one view or the other, but in hopes that better understanding will come from his contribution. There are few situations we know of where close observations and controlled studies are being made on native large herbivores on original prairie remnants or reconstructions. It is suggested that studies which attempt to document more closely the interaction of all original prairie components are urgently needed.

RESTORATION AND MANAGEMENT

Reestablishment of prairie species in areas they once dominated has been a goal for many of us in the midwest. It is commonplace today to hear of federal, state, and county conservation agencies, schools, and individuals attempting to restore a prairie. Papers in this section document some of these efforts, from the early stages of establishment as reported by Bragg, Stephens, and Becic in Nebraska to the longer established areas by Zimmerman and Schwarzmeier in Wisconsin and Schramm in Illinois.

Management regularly involves fire, with managers developing their own procedures, as described by Hulbert for the Kansas prairie, and by Blewett for a wildlife refuge.

Prairie establishment along highways has been presented in considerable detail by Cull in Illinois and Nuzzo in Wisconsin, with comments from Tipsword on landscape architecture and Thompson on a prairie trail.

Several other papers complete this section including the use of chemicals in controlling weeds by Woehler and Martin, strip mine reclamation with prairie species by Schramm and Kalvin, large scale restoration in Wisconsin by Reed and Schwarzmeier, impact of reservoir water on Kansas prairie by Harrington and Capel, commercial seed production by Wheeler and Tessene, and a note on management of prairie fens by Zimmerman.

ALLWINE PRAIRIE PRESERVE: A REESTABLISHED BLUESTEM GRASSLAND RESEARCH AREA

Thomas B. Bragg
Department of Biology
University of Nebraska at Omaha
Omaha, Nebraska 68101

ABSTRACT

Allwine Prairie Preserve is a 65 ha, reestablished grassland research area developed on previously cultivated and terraced cropland. The Preserve, situated in the Bluestem Prairie region of eastern Nebraska, was donated to the University of Nebraska at Omaha in 1959 and seeded with native grasses in 1970. An extensive grass cover is now extant both on the 53 ha Tallgrass Area, dominated by big and little bluestem (Andropogon gerardii and A. scoparius, 54% and 12% coverage, respectively), sideoats grama (Bouteloua curtipendula, 10%), and Indiangrass (Sorghastrum avenaceum, 10%), and on the 3 ha Midgrass Area, predominantly little bluestem (63%) and sideoats grama (28%). Management of the Preserve varied from 1971 to 1976 at which time a long-term management program was initiated that included various combinations of burning and mowing. Soils of the Preserve are primarily silt and silty clay loams with slopes varying from 1 to 30%; both north and south aspects are represented. Four small but complete drainage areas occur within the Preserve, although extensive terracing of the slopes may limit their use for research. Two small farm ponds, an adjoining 4 ha woodland, and space for cultivated plots and animal pens is available for research and training. A resident manager controls access to the area; use of the Preserve for research and teaching is coordinated through the Department of Biology, University of Nebraska at Omaha.

INTRODUCTION

Extensive cultivation and land development over the last century has resulted in a substantial decline in the extent of native bluestem prairie. As a consequence of this trend, there has been an increase in studies on native grassland reestablishment. Native grass stands have been successfully established in Illinois, Iowa, Michigan, Texas, Wisconsin and elsewhere (Bland 1970, Ode 1970, Schulenberg 1970, Anderson 1972, Springer and Schramm 1972, Graham 1975, Riskind and Davis 1975). Purposes underlying grassland reestablishment vary with the anticipated use of the area. Restoration for biological purposes provides protected habitat for native flora and fauna with the objective being an approximation of the conditions of the original, native ecosystem. Practical applications of prairie plant reestablishment, which rely on the evolutionary adaptation of native flora to local environments, include reestablishing grazing land on previously cultivated or overgrazed farmland, and establishing low maintenance vegetative cover along roadways (Landers 1972, Ode 1972, MacLauchlan 1973). In addition, native plants may be used on a smaller scale for erosion control, landscaping, reproduction of early settlement vegetative conditions at historical sites, and other, similar activities (Hutchinson 1973, MacLauchlan 1973, Brakeman 1975, Dyas 1975).

Allwine Prairie Preserve, having been recently seeded to native grasses, lends itself to studies pertinent to both the initial phases of grassland reestablishment and to the long-term effects of various types of management. The intent of this paper is to support research at Allwine Prairie Preserve by describing the research area, summarizing available information, and suggesting research needs.

GENERAL HISTORY AND DESCRIPTION

Allwine Prairie Preserve (Fig. 1), 65 ha (160 acres) of previously cultivated and terraced farmland, is located in Douglas County, Nebraska

Table 1. Physical properties of selected soils from Allwine Prairie Preserve.[1] Soil samples of the upper 15 cm. of the solum were collected during August, 1975. ppm = parts per million, T = terraced, u-T = unterraced.

Soil characteristic	MIDGRASS AREA upland	MIDGRASS AREA slope T	MIDGRASS AREA slope u-T	TALLGRASS AREA upland	TALLGRASS slope upper T	TALLGRASS slope upper u-T	TALLGRASS slope lower-1 T	TALLGRASS slope lower-1 u-T	TALLGRASS slope lower -2	TALLGRASS low land
Residual nitrate (ppm)	1.5	1.5	1.3	1.6	1.5	1.4	1.6	1.4	1.5	2.6
Organic matter (%)	2.5	1.6	1.4	2.8	1.3	1.2	1.7	2.3	3.4	3.4
pH	6.1	7.0	6.4	6.0	6.8	6.8	7.7	6.4	6.2	6.9
Phosphorous (ppm)	5.0	4.3	7.0	4.7	5.3	4.6	1.7	2.2	3.2	49.0
Potassium (ppm)	248	206	204	251	197	182	183	175	252	723
Soil texture (%):										
Sand	-	15	11	-	21	12	11	12	-	17
Silt	-	53	56	-	49	56	59	56	-	56
Clay	-	32	33	-	30	32	30	32	-	27
Soil type[2]	MaD	MfE2	MfE2	MaD	MfE2	MfE2	MeD2	MeD2	StE2	Cg

[1] Data extracted from Bragg (unpubl.) [2] See Fig. 3.

Table 2. Seeding rate for native grass planting at Allwine Prairie Preserve, May 1970.

Area and Species[1]	Variety	Pure live seed (kg/ha)
TALLGRASS AREA:		
UPLAND		
big bluestem (*Andropogon gerardii*)	Pawnee	2.8
little bluestem (*A. scoparius*)	Aldous	1.7
Indiangrass (*Sorghastrum avenaceum*)	Nebraska 54	1.1
sideoats grama (*Bouteloua curtipendula*)	Trailway	1.1
switchgrass (*Panicum virgatum*)	Pathfinder	0.6
DOUBLE-SEEDED LOWLAND		
big bluestem (*Andropogon gerardii*)	Pawnee and Kaw	5.6
Indiangrass (*Sorghastrum avenaceum*)	Nebraska 54	2.2
Switchgrass (*Panicum virgatum*)	Pathfinder	1.1
MIDGRASS AREA, UPLAND:		
sideoats grama (*Bouteloua curtipendula*)	Trailway	3.4
little bluestem (*Andropogon scoparius*)	Aldous and Blaze	2.2
blue grama (*Bouteloua gracilis*)	(Colorado source)	2.2
buffalograss (*Buchloe dactyloides*)	(Colorado source)	2.2

[1]Scientific and common names from McGregor (Check list of Great Plains flora with synonyms, 1973 unpubl.) and Anderson and Owensby (1969) respectively.

SE¼ Sect 23 T16N R11E, approximately 20 km northwest of the University of Nebraska at Omaha Campus. It is situated in the rolling loess hills of eastern Nebraska in the region designated as Bluestem Prairie by Küchler (1964).

The quarter-section of land was donated to the University of Nebraska at Omaha in 1959 by A. A. Allwine for use as a research area. The individual leasing the farm at the time of donation was permitted to remain until the lease expired; as a consequence, the Preserve continued in cultivation from 1959 to 1968. By 1968 weeds were extensive over much of the Preserve since no effective weed control measures were applied by the farmer. In 1968, in addition to the 40 ha in cultivation, 6 ha of red clover (*Trifolium pratense*) had been established on the upland and slope immediately east of the entrance road and 10 ha of alfalfa (*Medicago sativa*) was established on the upland and upper slopes in the northwest corner of the Preserve. Terraces, which remain a distinctive feature on the slopes of the Preserve, were first established in the mid-1950's and reformed in 1965.

Interior roads divide the Preserve into three sub-units, which are now designated the South Tallgrass Area (30 ha), the North Tallgrass Area (23 ha), and the Midgrass Area (3 ha) (Fig. 2). In addition to the recently seeded grassland areas, the Preserve includes two small farm ponds, an adjoining 4 ha woodland, and space for cultivated plots and animal pens. Hunting, fishing, and collection of flora and fauna are restricted to research-related activities. A resident manager controls access to the Preserve.

The average annual precipitation in east-central Nebraska is 71 cm, with most occurring as rainfall from April through September. Snowfall occurs primarily from November through March and averages 81 cm annually, although the amount varies substantially from year to year. Normal temperatures vary from -22°C in January to 39°C in July, with a frost-free period of approximately 167 days. Prevailing winds are from the south-southwest in the summer and from the northwest in the winter. Climatic information is from Bartlett (1975).

Soils of Allwine Prairie are primarily silt and silty clay loams of the Mollisol and Entisol soil orders; slopes vary from 1 to 30% with both north and south aspects represented (Fig. 3). Four small but complete drainage areas occur within the Preserve, but the strong terraces that occur on most slopes, indicated by the light colored bands on Fig. 2, limit their usefulness for research by interfering with natural drainage patterns. Physical properties of the soil vary between topographic locations and between terraced and unterraced areas (Table 1).

SEEDING AND INITIAL MANAGEMENT: 1970 TO 1976

In 1969, with the cooperation of the U.S.D.A. Soil Conservation Service, the initial steps were taken to seed the Preserve to native grasses. During the spring of 1969, the entire cultivated portion of the Preserve, including the areas with red clover and alfalfa, was plowed and planted to grain sorghum. This step was intended to reduce the amount of weeds in the area to be seeded. In May 1970, 56 ha were seeded to native grasses (Fig. 4; species and seeding rate in Table 2). Grass seed was drilled directly through the sorghum stubble using a Nesbett drill. Because of unusually dense weeds, the lowland area was prepared by discing once on 11 May and again on 21 May after which the area was drilled with a double amount of seeds. A four meter wide strip along both sides of the lowland, interior road was seeded with blue grama and buffalograss. Waterways and turn-rows, in which smooth brome (Bromus inermis) and reed canarygrass (Phalaris arundinacea) were extensive, were neither plowed nor seeded.

Weedy grasses and forbs, principally foxtail (Setaria spp.), with lesser amounts of horseweed (Conyza canadensis), wild lettuce (Lactuca canadensis), and, in the lowland, smartweed (Polygonum spp.), dominated the seeded area during the first growing season. The entire area was mowed at least three times from June through August, 1970, in an attempt to reduce the weed competition. The vegetation was shredded and evenly scattered over the field. The following June, 1971, because of continued weed problems, the entire seeded portion was sprayed with 2,4-D, a phenoxy herbicide, using a tractor-pulled rig. The entire area was mowed twice during July and August and the vegetation shredded and left on the field. Brome waterways and turn-rows were "scalped" (mowed very close to the ground). Again in June, 1972, 2,4-D was used in areas where weeds were dense; the entire area was mowed in August and the vegetation baled and removed. Brome waterways and turn-rows were again scalped. Due to a baling wire shortage, only a small portion of the Preserve was mowed in 1973. Mowing was completed during August and the vegetation was baled. Many bales were left on the field, but they have since been removed. In 1974, 1975, and 1976, selected areas within the Preserve were burned in April and mowed in August; the exception was 1976 when mowing was completed by the end of July. Mowed vegetation was baled and removed.

Seeding success. The first extensive, quantitative evaluation of the grass seeding was conducted in 1975 (Becic 1976). A good stand of native grass had become established throughout, although some variations occurred between terraced and unterraced, and between burned and unburned areas (Table 3).

LONG-TERM MANAGEMENT

During 1976, a long-term management plan was established that included various combinations of burning and mowing management (Fig. 2). This plan is presently being implemented.

Burning management will take place during April of each year. This time of burning favors native warm-season vegetation and reduces invasion by woody plants (Owensby and Anderson 1967, Hulbert 1973, Owensby and Smith 1973, Bragg and Hulbert 1976). The sequence of burning is such that only one of the three areas will be burned each year leaving the remainder of the Preserve as a refuge for animals. The three-year burn cycle should also permit small animal populations to recover from the effects of burning (Schramm 1970, Springer and Schramm 1972).

Mowing, the only source of income from the Prairie, is also the principal use of the few remaining unplowed prairies in eastern Nebraska. Mowing at Allwine Prairie will be completed during July, although most native prairie remnants are mowed for hay as late as September. July mowing permits additional growth and flowering of native plants, particularly grasses, while still providing a good crop of prairie hay. The mowing date may be moved earlier in the year if preliminary studies, which indicate substantially greater regrowth from May or June mowings (Bragg, unpublished data), are supported by additional evaluations. Unless otherwise specified, mowing includes removal of the clipped vegetation.

Combined mowing and burning, suggested as a possible means of successful grassland management by Becic and Bragg (1978), is also included in the long-term management plan. This combination involves an annual July mowing and a three-year, April burn cycle. Other combinations, incorporating fall burning, annual burning, spring mowing, and mowing but leaving the litter, will be evaluated in management study quadrats.

Table 3. Percent vegetative cover on Allwine Prairie Preserve, 1975[1]. Burn = area burned in April 1975, T = terraced portion of slopes, u-T = portion of slope situated between terraces, tr = less than 0.5% coverage.

VEGETATION	MIDGRASS AREA, BURNED upland	slope T	slope u-T	COMBINED NORTH AND SOUTH TALLGRASS AREAS upland	slope T burn	slope T unburn	slope u-T burn	slope u-T unburn	lowland
big bluestem	1	5	0	45	64	60	47	44	67
little bluestem	65	72	53	11	13	14	20	13	3
Indiangrass	0	0	tr	10	14	17	2	15	3
sideoats grama	14	40	30	9	12	13	12	14	1
switchgrass	0	1	0	3	9	2	3	5	17
blue grama	5	6	3	0	0	0	0	0	0
other grasses	tr	8	tr	1	22	2	tr	tr	3
forbs	tr	6	6	14	2	17	tr	24	3
open soil	-	4	-	-	4	4	45	17	-

[1] Data extracted from Bragg (1976) and Becic and Bragg (1977).

Fig. 1. View of Allwine Prairie Preserve, September 1976. Photo taken from northwest corn viewing south.

Fig. 2. Long-term management plan for Allwine Prairie Preserve. B-0 = unburned, B-3 = burned every third year in April, M-0 = unmowed, M-1 = mowed annually in July. Unmarked areas are woodlands or areas incorporating farm structures. Size is 65 ha (160 acres).

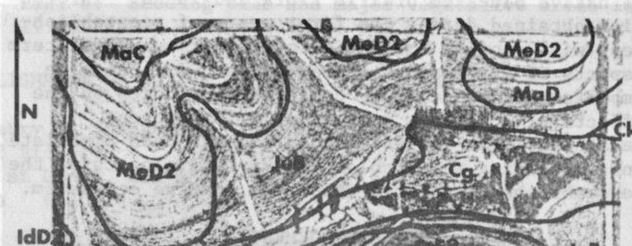


Fig. 3. Soils of Allwine Prairie Preserve. Cg = Colo silty clay loam (level); Ck = Colo and Kennebec clayey and silty soils; IdD2 = Ida silt loam (7 to 17% slopes, eroded); JuB = Judson silt loam (3 to 7% slopes); MaC and MaD = Marshall silty clay loams (3 to 7% and 7 to 11% slopes respectively); MeD2 = Marshall-Ponca silty clay loam (7 to 11% slopes, eroded); MfE2 = Marshall-Ponca soils (11 to 17% slopes, eroded); StE2 = Steinauer clay loam (11 to 30% slopes, eroded) (Bartlett 1975).

RESEARCH

Although Allwine Prairie is frequently used by University, high school, and grade school classes, its principal purpose is for research. Research studies completed or now under way include a survey of the grassland vegetation (Becic 1976), effects of terraces, burning, and mowing (Bragg 1976, Becic and Bragg 1977), forb establishment, effects of burning and mowing on small mammal populations, and winter diet and nest distribution of ring-necked pheasant (Phasianus colchicus).

Many additional studies are needed to fully describe the biota of the recently established grassland. White-tailed deer (Odocoileus virginianus), muskrat (Ondatra zibethicus), and wood ducks (Aix sponsa) are among the many animals observed on the Preserve, but a detailed survey has yet to be conducted. Studies are also needed on the vegetative composition of the woodland areas, the bryophytes of the Preserve, and the flora and fauna of the farm ponds. More detailed studies on various environmental parameters, such as the soil, would also be valuable. These and other studies need to be conducted within the first few years of vegetative development in order to provide adequate information for subsequent comparative studies.

CONCLUSION

Allwine Prairie Preserve provides a unique location for studies pertinent to the reestablishment of native bluestem prairie flora and fauna. Information obtained during the first years of reestablishment will provide insight into the various short-term aspects of grassland restoration, and will also be important in subsequent, comparative studies on the effects of long-term management. The present management plan is designed to support both immediate and continuing research on the various aspects of the reestablishment of this important, native ecosystem.

ACKNOWLEDGEMENTS

This paper is presented on behalf of the many faculty members of the Department of Biology, University of Nebraska at Omaha, who have worked to establish and maintain Allwine Prairie Preserve. In addition I would like to express my appreciation to Mr. Charles Eberspacher, of the U.S. Department of Agriculture Soil Conservation Service, for his continued assistance in our efforts.

LITERATURE CITED

Anderson, Kling L., and Clenton E. Owensby. 1969. Common names of a selected list of plants. Agr. Exp. Sta. Tech. Bull. 117, Kansas State Univ., Manhattan. 62 p.

Anderson, Roger C. 1972. Prairie history, management, and restoration in Southern Illinois. In: James H. Zimmerman, ed. Proc. Second Midwest Prairie Conf. Univ. Wisc. Arboretum, Madison. pp. 15-21.

Bartlett, Paul A. 1975. Soil survey of Douglas and Sarpy Counties, Nebraska. U.S. Dept. Agr. Publ., in cooperation with the Univ. Neb. Conservation and Survey Div. 80 p.

Becic, James N. 1976. Grassland reestablishment under burning and mowing management in eastern Nebraska. M.A. Thesis, Univ. Neb. Omaha. 25 p.

Becic, James N., and Thomas B. Bragg. 1978. Grassland reestablishment in eastern Nebraska using burning and mowing management. These Proceedings.

Bland, Marilyn K. 1970. Prairie establishment at the Michigan Botanical Gardens. In: Peter Schramm, ed., Proc. Symp. Prairie and Prairie Restoration. Knox College Biol. Field Station Spec. Publ. No. 3. pp. 46-47.

Bragg, Thomas B. 1976. The effect of terraces on reestablishing native grasslands in eastern Nebraska. Abstracts of Papers Presented at 29th Annual Meeting, Soc. Range Management. p. 39. (Abstr.)

Bragg, Thomas B., and Lloyd C. Hulbert. 1976. Woody plant invasion of unburned Kansas bluestem prairie. J. Range Mgmt. 29:19-24.

Brakeman, Walter G. 1975. Industry uses of prairie grasses for erosion control and landscaping. In: Mohan K. Wali, ed., Prairie: A Multiple View. Univ. N.D. Press, Grand Forks. pp. 417-418.

Dyas, Robert W. 1975. Landscape design with prairie plants. In: Mohan K. Wali, ed., Prairie: A Multiple View. Univ. N.D. Press, Grand Forks. pp. 411-418.

Graham, B. F. 1975. CERA: An outdoor biological laboratory. In: Mohan K. Wali, ed., Prairie: A Multiple View. Univ. N.D. Press, Grand Forks. pp. 379-382.

Hulbert, Lloyd C. 1973. Management of Konza Prairie to approximate pre-whiteman fire influences. In: Lloyd C. Hulbert, ed., Third Midwest Prairie Conf. Proc. Div. Biol., Kansas State Univ., Manhattan. pp. 14-17.

Hutchinson, D. E. 1973. Landscaping with natives. In: Lloyd C. Hulbert, ed., Third Midwest Prairie Conf. Proc. Div. Biol., Kansas State Univ., Manhattan. pp. 8-9.

Küchler, A. W. 1964. Potential natural vegetation of the coterminous United States. Amer. Geog. Soc. Spec. Publ. No. 36. 116 p.

Landers, Roger Q. 1972. The use of prairie grasses and forbs in Iowa roadside. In: James H. Zimmerman, ed., Proc. Second Midwest Prairie Conf. Univ. Wisc. Arboretum, Madison. pp. 180-183.

MacLauchlan, Robert S. 1973. The role of the Soil Conservation Service's work with plant material. In: Lloyd C. Hulbert, ed., Third Midwest Prairie Conf. Proc. Div. Biol., Kansas State Univ., Manhattan. pp. 9-12.

Ode, Arthur H. 1970. Some aspects of establishing prairie species by direct seeding. In: Peter Schramm, ed., Proc. Symp. Prairie and Prairie Restoration. Knox College Biol. Field Station Spec. Publ. No. 3. pp. 52-60.

Ode, Arthur H. 1972. A rationale for the use of prairie species in roadside vegetation management. in: James H. Zimmerman, ed., Proc. Second Midwest Prairie Conf. Univ. Wisc. Arboretum, Madison. pp. 174-179.

Owensby, Clenton E., and Kling L. Anderson. 1967. Yield responses to time of burning in the Kansas Flint Hills. J. Range Mgmt. 20:12-16.

Owensby, Clenton E., and Ed F. Smith. 1973. Burning true prairies. In: Lloyd C. Hulbert, ed., Third Midwest Prairie Conf. Proc. Div. Biol., Kansas State Univ., Manhattan. pp. 1-4.

Riskind, David H., and Arnold G. Davis. 1975. Prairie management and restoration in the state parks of Texas. In: Mohan K. Wali, ed., Prairie: A Multiple View. Univ. N.D. Press, Grand Forks. pp. 369-373.

Schramm, Peter. 1970. Effects of fire on small mammal populations in a restored tall-grass prairie. In: Peter Schramm, ed., Proc. Prairie and Prairie Restoration. Knox College Biol. Field Station Spec. Publ. No. 3. pp. 39-41.

Schulenberg, Ray. 1970. Summary of Morton Arboretum prairie restoration work, 1963 to 1968. In: Peter Schramm, ed., Proc. Symp. Prairie and Prairie Restoration. Knox College Biol. Field Station Spec. Publ. No. 3. pp. 45-46.

Springer, J. Tucker, and Peter Schramm. 1972. Effects of fire on small mammal populations in a restored prairie. In: James H. Zimmerman, ed., Proc. Second Midwest Prairie Conf. Univ. Wisc. Arboretum, Madison. pp. 91-96.

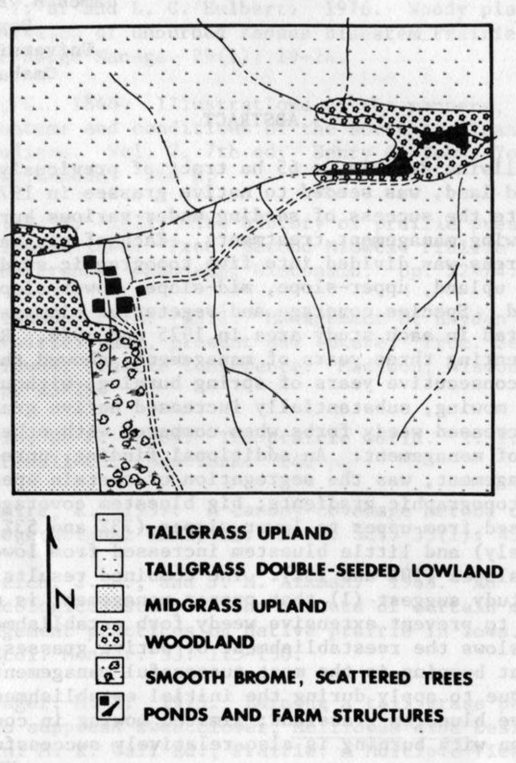


Fig. 4. Seeding plan and major vegetative areas in 1970.

NOTES ON EFFECTS OF TERRACES ON THE REESTABLISHMENT OF NATIVE BLUESTEM GRASSLANDS

Thomas B. Bragg and Larry J. Stephens
Department of Biology
University of Nebraska at Omaha, Box 688
Omaha, Nebraska 68101

Interest in the reestablishment of native grass stands on previously cultivated and frequently terraced cropland has increased as the amount of remaining native prairie declines. This study was initiated to determine the effects of agricultural terraces on grassland reestablishment. It was conducted at Allwine Prairie Preserve, 65 ha of previously cultivated and terraced cropland, that was seeded to native grasses in 1970. The 53 ha tallgrass area was seeded with big and little bluestem (Andropogon gerardii and A. scoparius), sideoats grama (Bouteloua curtipendula), Indiangrass (Sorghastrum nutans), and switchgrass (Panicum virgatum); the 3 ha midgrass area was seeded with little bluestem, sideoats grama, blue grama (Bouteloua gracilis) and buffalograss (Buchloe dactyloides). In April 1975 a portion of the tallgrass area and the entire midgrass area were burned as part of the management of the preserve. This combination of seedings and burning management provided three areas for this study; (1) unburned tallgrass area, (2) burned tallgrass area, and (3) burned midgrass area. Within each study area, four topographic locations were separately evaluated to determine the effects of terracing on grassland reestablishment; (1) the slope centered between two terraces, (2) the terrace-depression, (3) the terrace-top, and (4) the terrace-slope, located two meters downslope from the terrace-top. Vegetative composition was evaluated in 1975 by recording species coverage for 150, 1-dm^2 microplots in each of the management/terrace locations.

Combined data characterize the tallgrass area as predominantly big bluestem (56% coverage) with less little bluestem (15%), sideoats grama (12%), and Indiangrass (5%). The midgrass area was dominated by little bluestem (67%) and sideoats grama (37%). Coverage of the dominant grasses was similar on both burned and unburned tallgrass area locations, but statistically significant differences were found between certain terrace and slope locations. In all areas, the maximum coverage of little bluestem occurred in the terrace-depression (average coverage of 44%) while sideoats grama and blue grama favored terrace-tops (29% and 8%). On the tallgrass area, Indiangrass favored terrace-depression and terrace-top locations (20% and 16%); big bluestem coverage was greatest in the terrace-depression and on terrace-slope locations (70% and 69%). No species reached a maximum coverage on the slopes. With native, perennial grass cover not yet continuous, weedy grass and forb species were abundant in some locations with the greatest coverage occuring on terrace-tops (18%) and terrace-slopes (23%). Annual grasses dominated the weedy species coverage on burned areas while forbs dominated on unburned areas. Total biomass differences were substantial between the slope (362 gm/m^2 and the combined terrace locations (676 gm/m^2).

The combined results of this study show that five years of vegetative development resulted in the segregation of species on terraced and unterraced portions of a reestablished grassland with all species favoring some terrace location.

GRASSLAND REESTABLISHMENT IN EASTERN NEBRASKA USING BURNING AND MOWING MANAGEMENT

James N. Becic and Thomas B. Bragg
Department of Biology
University of Nebraska at Omaha
Omaha, Nebraska 68101

ABSTRACT

Allwine Prairie, a 65 ha tract of previously cultivated land, was seeded to native grasses in 1970 to evaluate the success of seeding under various burning and mowing management treatments. Each of six management areas was divided into five topographic study areas; upland, upper-slope, mid-slope, lower-slope, and lowland. Species coverage and vegetative biomass were evaluated in each study area in 1975 and 1976. Results, representing three years of management, showed that three consecutive years of spring burning, without summer mowing, substantially increased native grasses and decreased weedy forbs when compared with other types of management. An additional finding, unrelated to management, was the segregation of certain species along topographic gradients; big bluestem coverage increased from upper to lower slopes (33% and 53% respectively) and little bluestem increased from lower to upper slopes (10% and 13%). The combined results of this study suggest (1) that proper management is necessary to prevent extensive weedy forb establishment which slows the reestablishment of native grasses and, (2) that burning is the most successful management technique to apply during the initial establishment of a native bluestem grassland; limited mowing in conjunction with burning is also relatively successful.

INTRODUCTION

Bluestem prairie (Andropogon-Panicum-Sorghastrum) (Küchler 1964) once covered much of eastern Nebraska (Weaver 1954, Weaver and Albertson 1956, Costello 1969) but extensive cultivation since the mid-1800's has eliminated most of these native prairie stands. Four types of management have been widely used in the remaining native bluestem prairie ranges; these are burning, mowing for hay, grazing, and prevention of burning, mowing or grazing. Historically, prairie fires occurred frequently in both spring and fall and were initiated by lightning and native-American Indians (Catlin 1848, Komarek 1964, 1966, Anderson 1972). Recent studies on native bluestem prairie suggest that burning decreases woody plant invasion, prevents litter accumulation, improves nutrient release, and increases soil temperature (Kucera and Koelling 1964, Kucera 1970, Richards 1972, Hulbert 1973, Bragg and Hulbert 1976). Grazing by large, native herbivores was extensive but probably less intense than present cattle grazing which, depending on intensity, has been shown to increase soil compaction, change vegetative species composition by selective grazing, and decrease depth and quality of grass roots (Weaver 1950, Voight and Weaver 1951, Owensby et al. 1973). Mowing for hay, a common practice in bluestem prairie, appears to decrease soil nutrients and grass productivity, and increase annual weeds and soil compaction (Johnson 1970, Cawley 1972, Christianson 1972, Smeins 1973). The combined results of these studies indicate that native bluestem prairies are best managed by judicious burning (Ehrenreich and Aikman 1963, Owensby and Smith 1973, Heitlinger 1975, Hill and Platt 1975).

Studies on previously cultivated areas that have been reseeded to native grasses suggest results similar to those obtained for native bluestem prairie (Bland 1970, Schulenberg 1970, Schumacher 1975, Bragg 1976), although extensive work has not been done in this area. This study was designed to evaluate the effect of various management conditions on the reestablishment of a bluestem prairie.

METHODS

Allwine Prairie Preserve (Bragg 1978) is a 65 ha, restored grassland research site situated within the portion of eastern Nebraska designated by Küchler (1964) as a bluestem prairie. The Preserve consists of gently rolling, terraced, loess hills of both north and south aspect; hills range from 3% to 15% slope with a vertical terrace interval of approximately four meters. Soils are of the Mollisol and Entisol soil orders. The climate of the area is characterized by a mean annual precipitation of 71 cm, three-fourths of which falls from April through September. Local droughts occur when the time or distribution of precipitation is poor. Temperature averages from 1°C in January to 31°C in July with extremes of -23°C in January and 41°C in July common. The frost-free season averages about 167 days (climate and soils from Bartlett 1975).

The study area was uniformly seeded to native grasses in May 1970. Grass species included in the seeding plan were big bluestem (*Andropogon gerardii*, little bluestem (*A. scoparius*), Indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and sideoats grama (*Bouteloua curtipendula*). All seeded areas were mowed twice in each of 1970 and 1971, mowed once in 1972, and unmowed in 1973. The herbaceous vegetative cover is not continuous; bare ground is common throughout much of this newly established grassland.

The prairie was divided into 6 management areas within which specific study areas were delineated based on topographic location (Table 1). Study areas, evaluated during June and July of both 1975 and 1976, included upland (hilltop), upper-slope, mid-slope, lower-slope and lowland locations. Spring burning occurred in late April or early May and summer mowing occurred in late July or early August.

Vegetative composition was evaluated in 1975 systematically locating five, 2 x 10 m plots on each of the slope areas and ten, 2 x 10 m plots on each upland and lowland area. In each plot, ten 1-dm^2 microplots were randomly located and the canopy coverage of each species estimated using procedures developed by Daubenmire (1959). The vegetative evaluations for 1976 were limited to 16-m^2 exclosures situated on slope and upland positions. Ten 1-dm^2 microplots were randomly located within each exclosure and evaluated for canopy cover. For purposes of comparison, weedy forbs and species with coverage values less than 0.5% were grouped by using the maximum coverage value in the plot for any species of that group. Plant identifications were verified at the University of Nebraska at Omaha Herbarium; scientific and common names are from McGregor (1973) and Anderson and Owensby (1969), respectively.

Biomass was measured in August 1975 and 1976 by systematically locating and clipping three 0.5 m^2 plots in each of 5 selected study areas. The clipped vegetation was divided into grasses and forbs, oven-dried for 48 hours at 41°C, then weighed.

RESULTS AND DISCUSSION

Combined coverage and biomass data, representing three years of management, showed that three consecutive years of spring burning without summer mowing (BURN-3, MOW-0) substantially increased native grasses and decreased weedy forbs when compared to other types of management (Tables 1 and 2, Fig. 1). The increase in native grasses may be attributed to the intentional timing of the spring burn to coincide with the active germination and growth period of many weedy forbs thus resulting in either their destruction or inhibition. Summer mowing was timed early enough to allow for additional growth of native grasses, but by that time the weedy forbs had already disseminated their seeds. The increase in perennial weedy forbs with mowing may be the result of an increase in lateral vegetative growth, a response common in many species when closely mowed. An important factor in weedy forb success appears to be the removal of litter with mowing which encourages early seed germination and establishment by increasing the amount of sunlight reaching the soil surface. This advantage is amplified where much soil is exposed in newly seeded grasslands.

One additional finding of interest was the apparent segregation of some species along topographic gradients. Big bluestem increased from upper-slope to lower-slope (33% and 54% coverage, respectively) as did switchgrass (3% and 5%); little bluestem decreased from 13% on the upper-slope to 10% on the lower slope (Fig. 2). Soil moisture gradients related to topography may explain these results.

This study suggests that weedy forbs in newly seeded grasslands are likely to remain abundant for several years unless properly controlled and may thus slow the establishment of desirable native grasses. Burning was found to be the most successful management practice to apply during the first years of reestablishment of a native bluestem grassland. Limited mowing in conjunction with a burning plan was also successful but to a lesser extent in encouraging native grass establishment.

LITERATURE CITED

Anderson, K. L. and C. E. Owensby. 1969. Common names of a selected list of plants. Agricultural Experiment Station, Kansas State University. Tech. Bull. 117. 62 p.

Anderson, R. C. 1972. Prairie history, management and restoration in Southern Illinois. Proc. Second Midwest Prairie Conference. Madison, Wisconsin. 15-20.

Bartlett, P. A. 1975. Soil survey of Douglas and Sarpy Counties, Nebraska. U.S. Dept. Agr. S.C.S. 79 p.

Bland, M. K. 1970. Prairie establishment at the Michigan Botanical Gardens. Proc. Symposium on Prairie and Prairie Restoration. Galesburg, Illinois. pp. 46-47.

Bragg, T. B. 1976. The effects of terraces on reestablishing native grasslands in eastern Nebraska. Abstracts of Papers. 29th Annual Meeting Soc. Range Manag. Omaha, Nebraska. p. 39.

Bragg, T. B. 1978. Allwine Prairie Preserve: a reestablished bluestem grassland research area (these proceedings).

Bragg, T. B. and L. C. Hulbert. 1976. Woody plant invasion of unburned Kansas Bluestem Prairie. J. of Range Manage. 29(1): 19-24.

Catlin, G. 1848. Illustrations of the manners, customs and conditions of the North American Indians. Vol. 2, 7th ed. Henry G. Bohn, York St. London. 266 p.

Cawley, E. T. 1972. The history of prairie preservation in Iowa. Proc. Second Midwest Prairie Conference. Madison, Wisconsin. pp. 22-24.

Christiansen, P. A. 1972. Management of Hayden Prairie: past, present and future. Proc. Second Midwest Prairie Conference. Madison, Wisconsin. pp. 25-29.

Costello, D. F. 1969. The prairie world. T. Y. Crowell Co., New York. 242 p.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. N. W. Sci. 33(1): 43-64.

Ehrenreich, J. H., and J. M. Aikman. 1963. An ecological study of the effects of certain management practices on native prairie in Iowa. Ecol. Monogr. 33: 113-130.

Heitlinger, M. E. 1975. Burning a tall grass prairie to suppress sweetclover, Melilotus alba Desr. In: M. K. Wali Ed., Prairie: A Multiple View. Grand Forks, North Dakota. pp. 123-132.

Hill, G. R., and W. J. Platt. 1975. Some effects of fire upon a tall grass prairie plant community in northwestern Iowa. In: M. K. Wali Ed., Prairie: A Multiple View. Grand Forks, North Dakota. pp. 103-113.

Hulbert, L. C. 1973. Management of Konza Prairie to approximate prewhite-man fire influences. Proc. Third Midwest Prairie Conference. Manhattan, Kansas. pp. 14-17.

Johnson, A. G. 1970. Fertility level of a hay-cropped prairie. Proc. Symposium on Prairie and Prairie Restoration. Galesburg, Illinois. pp. 26-27.

Komarek, E. V., Sr. 1964. The natural history of lightning. Proc. Third Tall Timbers Fire Ecology Conference. Tallahassee, Florida. pp. 139-183.

Komarek, E. V., Sr. 1966. The meteorological basis for fire ecology. Proc. Fifth Tall Timbers Fire Ecology Conference. Tallahassee, Florida. pp. 85-125.

Kucera, C. L. 1970. Ecological effects of fire on tallgrass prairie. Proc. Symposium on Prairie and Prairie Restoration. Galesburg, Illinois. p. 12.

Kucera, C. L. and M. Koelling. 1964. The influence of fire on composition of central Missouri Prairie. The Amer. Midl. Nat. 72: 142-147.

Küchler, A. W. 1964. Potential natural vegetation of the coterminous United States. Amer. Geogr. Soc. Special Pub. No. 36. 116 p.

McGregor, R. L. 1973. Check list of Great Plains flora with synonyms. Unpublished and privately circulated. Mimeographed copy of typescript obtained from the author. 175 p.

Owensby, C. E. and E. F. Smith. 1973. Burning true prairie. Proc. Third Midwest Prairie Conference. Manhattan, Kansas. pp. 1-4.

Owensby, C. E., E. F. Smith, and K. L. Anderson. 1973. Deferred-rotation grazing with steers in the Kansas Flint Hills. J. Range Manage. 26(6): 393-395.

Richards, M. S. 1972. Management of Kalsow Prairie. Proc. Second Midwest Prairie Conference. Madison, Wisconsin. pp. 30-33.

Schulenberg, R. 1970. Summary of Morton Arboretum prairie restoration work 1963 to 1968. Proc. Symposium on Prairie and Prairie Restoration. Galesburg, Illinois. pp. 45-46.

Schumacher, C. M. 1975. Rangeland - a proper prairie use. In: M. K. Wali Ed., Prairie: A Multiple View. Grand Forks, North Dakota. pp. 419-422.

Smeins, F. E. 1973. Influence of fire and mowing on vegetation of the Blackland Prairie of Texas. Proc. Third Midwest Prairie Conference. Manhattan, Kansas. pp. 4-7.

Voigt, J. W., and J. E. Weaver. 1951. Range condition classes of native midwestern pasture: an ecological analysis. Ecol. Monogr. 22: 39-60.

Weaver, J. E. 1950. Effects of different intensities of grazing on quantity of roots of grasses. J. Range Manage. 3(2): 100-113.

Weaver, J. E. 1954. North American Prairie. Johnson Publishing Co., Lincoln, Nebraska. 343 p.

Weaver, J. E., and F. W. Albertson. 1956. Grasslands of the Great Plains. Johnson Publishing Co., Lincoln, Nebraska. 395 p.

Table 1. Weedy forb coverage and biomass on combined upland, slope, and lowland positions. Numbers indicate relative values of vegetation sampled in June and July.

	MANAGEMENT HISTORY				YEAR			
	YEAR				1975		1976	
STUDY AREA	1974	1975	1976	REFERENCE CODE	coverage (%)	biomass (gm)	coverage (%)	biomass (gm)
Upland-1	burned & mowed	unburned & unmowed	BURNED	BURN-2 MOW-1	-	-	3.0	1.0
	"	unburned & MOWED	BURNED	BURN-2 MOW-2	-	-	21.0	66.0
Upland-2	burned & mowed	unburned & unmowed	UNBURNED	BURN-1 MOW-1	-	-	2.0	4.0
	"	unburned & MOWED	UNBURNED	BURN-1 MOW-2	-	-	18.0	49.0
Slope-1	burned & unmowed	burned & unmowed	BURNED	BURN-3 MOW-0	tr[a]	tr	0.0	0.0
	"	"	UNBURNED	BURN-2 MOW-0	tr	tr	tr	4.0
	"	burned & MOWED	UNBURNED	BURN-2 MOW-1	tr	tr	2.0	6.0
Slope-2	burned & mowed	unburned & unmowed	BURNED	BURN-2 MOW-1	24.0	38.0	33.0	5.0
	"	"	UNBURNED	BURN-2 MOW-1	24.0	38.0	58.0	35.0
	"	unburned & MOWED	UNBURNED	BURN-1 MOW-2	24.0	38.0	65.0	76.0
Lowland	burned & unmowed	burned & unmowed	burned	BURN-3 MOW-0	3.0	tr	-	-

[a] tr = less than 0.5.

Table 2. Average percent coverage of principal species in 7 study areas.

	YEAR																
	1975								1976								
	BURN-1 MOW-1				BURN-2 MOW-0			BURN-2 MOW-0	BURN-3 MOW-0	BURN-2 MOW-0	BURN-2 MOW-1		BURN-1 MOW-1		BURN-1 MOW-2		BURN-2 MOW-2
	up[a]	us	ms	ls	us	ms	ls	ll	ms	ms	up	ms	up	ms	up	ms	up
NATIVE GRASSES																	
Andropogon gerardii	51	42	39	47	50	46	45	57	44	37	42	55	68	67	34	45	33
Andropogon scoparius	11	14	11	11	6	22	31	3	25	48	12	18	7	3	12	9	24
Bouteloua curtipendula	8	5	21	18	22	4	9	1	11	6	19	10	3	23	7	10	10
Panicum virgatum	2	4	5	5	0	7	2	28	2	2	2	2	1	0	1	0	5
Sorghastrum nutans	14	10	2	3	5	1	0	7	1	1	28	5	15	3	18	0	12
WEEDY FORBS																	
Melilotus officinalis	1	18	0	1	0	0	0	0	0	0	0	5	2	67	9	33	19
Trifolium pratense	1	11	13	0	tr[b]	0	0	0	0	0	tr	10	0	56	5	83	0
Conyza canadensis	9	6	8	1	tr	tr	tr	tr	tr	tr	tr	tr	tr	0	tr	0	tr
Lactuca canadensis	4	6	6	2	tr	0	tr	6	0	tr	0	2	0	3	tr	1	0
Oxalis dillenii	2	1	tr	2	0	tr	tr	2	0	0	tr	0	tr	0	tr	tr	0

[a] up = Upland, us = Upper-slope, ms = Mid-slope, ls = Lower-slope, ll = Lowland.

[b] tr = less than 0.5% coverage.

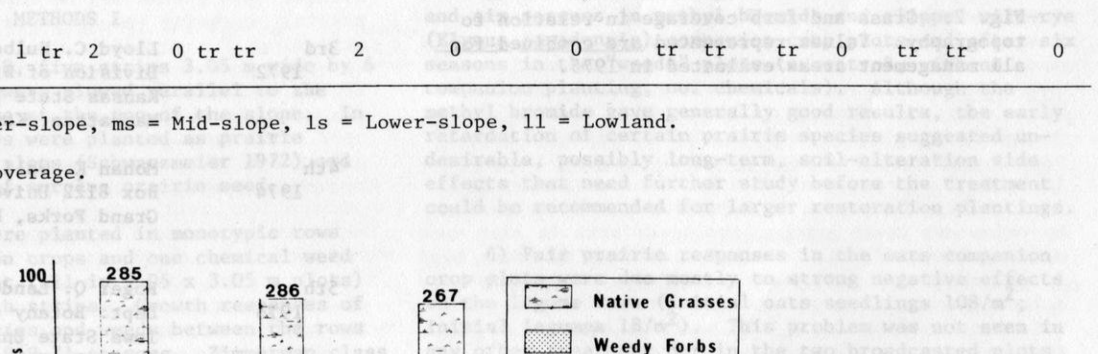


Fig. 1. Relative plant biomass for each management area. Number above each bar is absolute mean value of biomass (gm/m^2) for 1976.

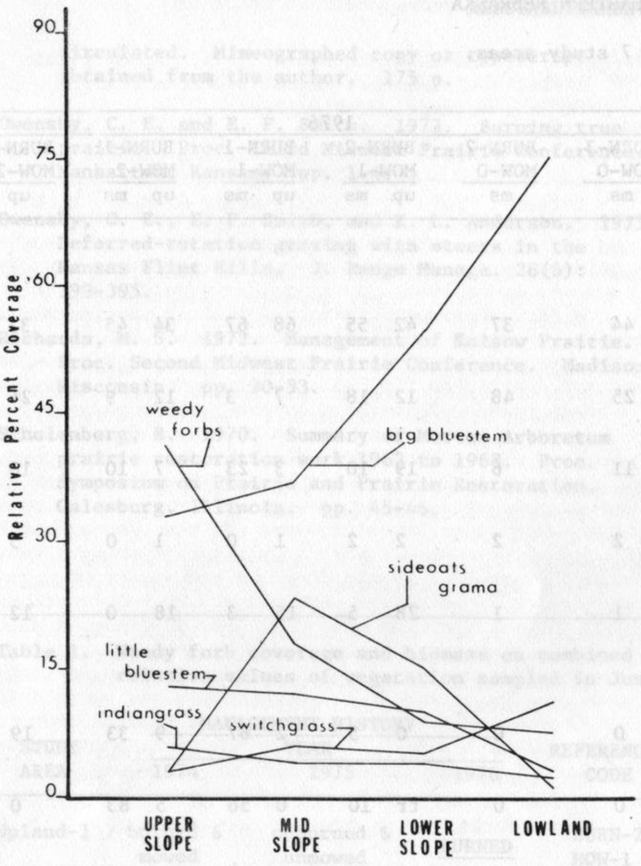


Fig. 2. Grass and forb coverage in relation to topography. Values represented are combined for all management areas evaluated in 1975.

MIDWEST PRAIRIE CONFERENCE CHAIRMEN

1st 1968 — Peter Schramm
Biology Department
Knox College
Galesburg, Illinois 61401

2nd 1970 — James H. Zimmerman
2114 Van Hise Avenue
Madison, Wisconsin 53705

3rd 1972 — Lloyd C. Hulbert
Division of Biology
Kansas State University
Manhattan, Kansas 66506

4th 1974 — Mohan K. Wali
Box 8122 University Station
Grand Forks, North Dakota 58202

5th 1976 — Roger Q. Landers
Dept. Botany & Plant Pathology
Iowa State University
Ames, Iowa 50011

6th 1978 — Ralph E. Ramey
Director: Glen Helen
Antioch College
Yellow Springs, Ohio 45387

EXPERIMENTAL PRAIRIE RESTORATION AT WINGRA OVERLOOK

James H. Zimmerman
Landscape Architecture Department
University of Wisconsin
Madison, Wisconsin 53706

and

J. A. Schwarzmeier
Waukesha County Park and Planning Commission
Waukesha, Wisconsin 53186

ABSTRACT

The study plots of Schwarzmeier (1972) at the U.W. Arboretum, Madison, Wisconsin, continue to indicate good prairie responses in most seeded replicates. Ascribed to low available soil moisture and phosphorus, the generally low weed competition level minimized differences in the success of weed-control procedures (chemicals, clipping, and planting of companion crops) but provided an opportunity for trial of larger-scale simplified prairie restoration procedures on the site which blended student training with research for maximum benefits at minimum cost.

INTRODUCTION

Wingra Overlook is a 2-ha (5-acre) 2-6% northwest-facing slope in the U.W. Arboretum adjacent to the southwestern side of Wingra Fen and Wingra Lake. It rises above the latter by ca 10 m (30 ft.). This former oak-prairie savanna on glacial till of sandy loam (Fox series) was pastured and possibly also tilled between ca 1840 and 1935, after which it was maintained as an old field by occasional burning or mowing until 1968.

METHODS I

In the fall of 1968, five strips 3.05 m wide by 6 m long (10 by 200 ft.) were plowed parallel to the adjacent McCaffrey Drive at the top of the slope. In spring, 1969, two strips were planted as prairie establishment research plots (Schwarzmeier 1972) and three for propagation of surplus prairie seed.

Prairie species were planted in monotypic rows across various companion crops and one chemical weed discouragement treatment (all in 3.05 x 3.05 m plots) in the two 61-m research strips. Growth responses of both these prairie species and weeds between the rows were recorded for the 1969-71 seasons. Zimmerman class observations on prairie plant counts or percentage cover and flowering counts for these rows were also made in 1972, 1973 and 1975. Results are given in Tables 1, 2 and 3. Some highlights of these findings follow:

RESULTS I

1) In the upper 10-15 cm of soil, the very low soil water containing capacity (Table 2) of 40.5% in the two research strips is lower than Curtis' (1959) figures for six of the 8 prairie-type upland communities in Wisconsin; only the "pine barrens" (36%) and "sand barrens" (29%) were lower. A loss of about 1/2 of the original top soil occurred when farmed; however, laterally-moving groundwater is probably available to the deeper roots on the site. Lower fertility (especially P) than in nearby Curtis Prairie was also noted (Table 4).

2) This drouthy infertile surface condition is probably the cause of the observed general low density and vigor of weeds usually highly competitive in prairie restoration. Although the generally good prairie responses in this case limit any stringent evaluation of the several weed-control treatments, this experience indicates that choice of a dry-mesic site can eliminate much of the difficulty in attaining a weedless appearance in prairie plantings. An important pre-tilling condition, which depicts this type of old-field site, is dominance of such species as Canada bluegrass (Poa compressa) and wild carrot (Daucus carota), which do not create dense foliage, sod or litter. On this site parsnip (Pastinaca sativa) was scarce, while quack grass (Agropyron repens) and sweet clover (Melilotus alba) were only locally abundant.

3) An initial perennial prairie seedling density of about 35 per m^2 has given the quickest results and most efficient use of seed so far in these research strips.

4) From four additional plots in the 61-m strips where prairie plants were broadcast-seeded, a strong negative relationship was found between prairie grass basal area and forb stem counts after 5 years growth.

5) Good prairie responses were observed after two and six seasons in methyl bromide and clipped wild-rye (Elymus canadensis) companion crop plots and after six seasons in the "weeds" plots (a control, with no companion planting, nor chemicals). Although the methyl bromide gave generally good results, the early retardation of certain prairie species suggested undesirable, possibly long-term, soil-alteration side effects that need further study before the treatment could be recommended for larger restoration plantings.

6) Fair prairie responses in the oats companion crop plots were due mostly to strong negative effects on the legume rows (initial oats seedlings $108/m^2$; initial legumes $18/m^2$). This problem was not seen in any other treatment nor in the two broadcasted plots having oats (initial oats and legumes were 89 and $14/m^2$ respectively).

7) Poor prairie responses occurred in the unclipped wild-rye and in all Indian grass (Sorghastrum nutans) plots except that the legumes did fairly well in the latter. Observations of summer grazing by cottontail rabbits and white-tailed deer in the area suggest that the dense blocks of standing Sorghastrum excluded these herbivores from access to the highly preferred plants of Aster laevis, Lespedeza and Petalostemum.

8) In these research strips, clipping was consistently useful in releasing prairie seedlings only in the wild rye companion crop and "weeds" plots. Clipping was done in the first two summers when a weed or companion crop canopy developed at least 0.3 m above the prairie seedlings. Cutting was normally down to the level at which damage to prairie seedlings would

first become noticeable; it averaged 18.3 cm (7.2 inches) the first season and 28 cm (11 inches) the second season.

METHODS II

The ease of prairie establishment on this site offered an opportunity to demonstrate relatively low-cost restoration using minimal seed and soil preparation, planting, and after-care procedures. Additional anticipated benefits from converting the entire 2 ha to prairie were opportunities for: 1) restoring a scenic lake vista to presettlement vegetation; 2) continuing restoration experiments through a catena including low prairie, fen and marsh; 3) repeatedly involving youth, college classes, and visiting groups in the experience of collecting and planting prairie seeds and measuring plant responses; 4) diverting teaching pressure from the heavily-used Curtis and Greene Prairies; 5) experimenting with forb-enhancement techniques; and 6) comparing results in diverse seasons. The existing experimental plots and relic species would provide additional long-term seed sources for natural spread downslope.

Accordingly, three 0.1-ha (0.25-acre) contour strips 7 m wide by 170 m long (20 x 500 feet) were spring-plowed, disced, and planted mostly within a week, one each in 1974, 1975 and 1976, successively downslope from the 61-m strips to the peatland edge. Three meter-wide strips of original Poa compressa sod were left between plowed strips as travel lanes and erosion barriers. Erosion proved to be minimal; rough-plowing left contour ridges and deep cracks.

With two bags of seed per student, 50 species were hand-broadcast in 20 minutes by one college class in each 0.1-ha strip. The roughly-turned sod, which made walking difficult, was intentional to diversify seedling establishment conditions (dry to wet) and initiate the microtopography attained by ants and fossorial mammals in virgin prairie. The 1974 strip was divided into equal sections (no grasses, Elymus canadensis only, and all prairie grasses), with the forbs scattered throughout the strip. Seeding densities in all 3 years varied with availability and vagaries of hand-scattering but is roughly indicated in Table 5. Grass densities were intentionally kept low. Mostly collected in September in the Arboretum by volunteer youth groups, the seeds were in each case dry-overwintered, with minimal cleaning, in paper bags in an unheated foundationless wooded shed located near a frost pocket in adjacent east Curtis Prairie. The relative humidity was > 50%; scarcity of windows kept temperatures low through May.

RESULTS II

Results are summarized in Table 5. Great variability in "take" within strips can be ascribed to soil variability and concomitant weed distribution. Year-to-year variability in weather was probably responsible for the following responses:

1) The 1974 strip, plowed late (June 6), had a cool moist summer. Quackgrass, Canada bluegrass, and sweet clover were scarce through 1976 and much bare ground remained. It is too early to assess the prairie-grass-forb interactions; but some forbs have done well, especially the legumes. Over 30 of 100 seeded species have been detected.

2) The 1975 strip, plowed early (May 8), but not fully planted until June 2, had a warm summer that began wet but was very dry after July 1. Early plowing and moisture may have triggered the dense central area invasion by cool season weeds (sweet clover seedlings and quackgrass rhizomes). In 1976, when this dense flowering weed growth (1.0-1.5 m tall) threatened survival of the 1-year-old prairie seedlings, the plot was mowed on July 25 to a height of 10 cm, using a brush bull. As the prolonged 1976 drouth worsened, the sweet clover did not resprout, the prairie species responded very well, and the quackgrass tardily returned in October. Over 20 prairie species have been detected.

3) In both the 1974 and 1975 strips, Bouteloua, Kuhnia and Ratibida came in rapidly and abundantly, apparently benefitting from heat as did the other prairie grasses in all 3 years. The 3 species each began to flower in the same season planted in both years.

4) The 1976 strip varied from drouthy sandy loam to a more fertile organic soil with more weeds as the slope leveled off. Plowing was relatively late (May 24), with infrequent very low rainfall (4.9 cm from plowing till July 28). No prairie seedlings began to appear until after an isolated storm yielding 2 cm on July 28. In this very hot, dry season (daily high continuously above 27°C for 8 of 21 weeks; total rain 14 cm for May-October), the grasses and legumes grew very rapidly in the weed-free drier portions despite their late start, with flowering in Bouteloua, Petalostemum candidum, Lespedeza, and Panicum virgatum (but not Ratibida) in 6 weeks after germination. Although difficult to detect, Elymus seemed to suffer, as expected, from the late start and heat and drouth of 1975 and 1976. At least 8 prairie species have been detected in the 1976 strip.

5) Except for weedy sections of the 0.1 ha strips, open ground may be expected to remain free for natural reseeding (as observed in the 61-m research strips) or for remedial grass or forb seedings. There is also opportunity for controlled tests of fire, mowing, and herbivore exclusion for several years hence, following a general burn scheduled for spring, 1977. The forb-grass-weed balance may be expected to adjust itself for many years, providing continuing teaching opportunity.

CONCLUSIONS

1. Although the study site has a fairly typical physical environment for dry-mesic prairie species, its history and Fox loam soil cause a generally low potential for weed competition.

2. In the original 1969 experimental strips, generally high survival of seeded prairie species benefitted additionally from weed discouragement by many of the applications of companion crops, chemicals, and mowing. The most significant of these effects, which may be expected to be more varied and thusly less reliable in fertile mesic soils, are:

(a) mowed wild-rye as a companion crop and mowed "weeds" gave consistently good results;

(b) methyl-bromide gave generally good results but may have undesirable side effects;

(c) oats performed well except for the apparent antipathy towards legumes in the main

Table 1. Species Presence and Flowering Responses in Seeded Rows from Zimmerman Class Observations 1972, 1973 and 1975, Expressed as Average Number Per Treatment[1].

	TREATMENTS					TOTALS	CV[3]
	Methyl-Br.	Wild-rye	Oats	Indian Grass	Weeds[2]		
Plots Involved	1 & 2	3 & 4	5 & 6	7 & 8	9 & 10		
RESPONSE VARIABLES							
Row Forb Species Per Plot							
1972	9	9	8.5	8.5	8		
1973	8	9	7.5	6	7.5		
1975	6	7.5	6	5.5	7	32.	12.5%
1975 % $\bar{x}$[4]	94%	117%	94%	86%	110%	501	12.5%
Row Grass Species Per Plot							
1972	4	4	4	3	4		
1973	4	4	4	1	4		
1975	4	4	4	2	4	18.	24.7%
1975 % $\bar{x}$	111%	111%	111%	56%	111%	500.	24.7%
Row Species Flowering Per Plot							
1972	4	4.5	4.5	0.5	3		
1973	8	8	8	3	7		
1975	8.5	9	7	3	8	35.5	35.9%
1975 % $\bar{x}$	120%	127%	99%	43%	111%	500.	35.9%

[1] Treatment averages are presented because responses were very similar between mowed and unmowed.

[2] Comprised of volunteer weeds in plots 9 & 10 which acted as a companion crop.

[3] Coefficient of variation.

[4] Results for 1975 are also shown as % $\bar{x}$ (percent of mean).

experiment, and

(d) Indian grass gave poor results by quickly becoming highly-competitive, but may have protected surviving legumes and an aster from mammalian grazing in subsequent years.

For restorations where development of natural interrelationships is important, these weed discouragement recommendations may be sufficient on dry-mesic sites. Wild-rye appears to be a good native companion on both types of sites but does require handling the awns so seeds are separable at planting time. It often requires mowing at ca. 15 cm in the first two seasons. There seem to be potential limitations with all other treatments.

3) High initial seedling densities of mid- or late-successional (persistent 5 years or more) prairie grass species appear to be more suppressive than ordinary weeds. Generally this suppression was not noticeable for seedling densities below 35/m^2 during 1969-1976.

4) Satisfactory results from larger-scale minimal-preparation restorations on three 0.1-ha strips on this same site during 1974-1976 demonstrate, the possibility of blending unique training and research benefits with species compositional flexibility and diversity. It was also demonstrated that costs could be kept low because of student involvement and choice of a site favorable to praiire but not to weeds and brush.

ACKNOWLEDGEMENTS

We are indebted to Grant Cottam for advice on use of % $\bar{x}$ and on the sorting out of mowing effects from site and treatment effects, several U.W. Extension Ecology Apprenticeship classes which compiled field data, and many volunteer youth groups which collected seed under Rosemary Fleming, we wish to thank Wayne Pauly for processing seeds, and Elizabeth Blomquist, Connie Richard, Dave Hammond, Kurt Peters and Catherine Bruner for making detailed seedling counts. We gratefully acknowledge the willingness of the U.W. Arboretum to provide continuing research space and management staff for plowing, mowing and burning.

LITERATURE CITED

Curtis, J. T. 1959. The Vegetation of Wisconsin. Univ. Wisconsin Press. Madison.

Schwarzmeier, J. 1972. Competitional aspects of prairie restoration in the early stages. Proc. Second Midwest Prairie Conference. 122-139.

Table 2. Growth Responses in Seeded Rows Expressed as % $\bar{x}$, from Zimmerman Class Observations 1972, 1973 and 1975[1]

	Mowed					Unmowed						
Plot #:	1	3	5	7	9	2	4	6	8	10	Totals	CV[2]
3 Year Mean % $\bar{x}$ Legumes (4 spp.)	145.	146.	67.	40.	114.	140.	95.	73.	107.	72.	999.	36.8%
	mean mowed response: 102.4					mean unmowed response: 97.4						
3 Year Mean % $\bar{x}$ Composites (5 spp.)	121.	120.	96.	52.	130.	114.	111.	111.	28.	118.	1001.	33.3%
	mean mowed response: 103.4					mean unmowed response: 96.4						
3 Year Mean % $\bar{x}$ all Forbs (9 spp.)	132.	131.	83.	48.	122.	126.	104.	94.	66.	96.	1001.	28.6%
	mean mowed response: 103.2					mean unmowed response: 97.0						
1975 Average 8 Forb spp.	73.	115.	62.	73.	164.	114.	102.	92.	77.	130.	1000.	31.8%
4 Grass spp.	126.	126.	103.	54.	100.	112.	110.	96.	69.	105.	1001.	22.9%
	mean mowed response: 101.8					mean unmowed response: 98.4						
mean of 8 Forbs & 4 Grasses	100.	121.	83.	64.	132.	113.	106.	94.	73.	118.	1001.	23.4%
% Water Retaining Capacities of Soil[3]	42.4	41.8	40.3	38.6	40.7							
	44.	40.8	40.4	34.7	41.3						405.	5.75%

[1]1972-73 data were number of plants for nearly all species. In 1975, data were: no. floral stems--5 spp.; no. plants--4 spp. and percentage basal area--3 spp.

[2]CV is coefficient of variation.

[3]Water retaining capacity is the amount held against gravity minus the amount held at constant oven dry weight; expressed as a percentage from weight of water lost over soil dry weight; essentially the same as "Field Capacity", mean value is 40.5%.

Table 3. Early Growth Environment and Treatment Effects of Broadcast Planting of Prairie and Companion Crop Species.

		Oats		Wild-rye		
	Plot No.	1	3	2	4	$\bar{x}$
Companion Crop[1]	seedlings/m²[2]	92.	86.	72.	83.	
	culms/m²[2]	285.	318.	92.	154.	
Clipping Heights[2]	12 Aug. 1971	–	–	8 cm	8 cm	
	2 Sept. 1971	20 cm	20 cm	13 cm	13 cm	
	2 Oct. 1971	15 cm	15 cm	15 cm	15 cm	
	6 June 1972	23 cm	23 cm	23 cm	23 cm	
Serious Weedy Grasses[3]		140.%	135.%	127.%	71%	118.%
Prairie Species Established in 1972	Legumes	2	1	2	3	2
	Composites	1	1	1	0	.75
	Grasses	2	3	2	2	2.25
	Totals	5	5	5	5	
1975 Effects	Forb Plants/Plot	102.	58.	69	41.	67.5
	Prairie Grass Plants (clumps only)/Plot	63.	78.	78.	70.	72.0
	Prairie Grass % b.a.[4]	3.5%	4.8%	5.4%	6.0%	4.9%

[1] companion crop as of August 12, 1971.

[2] Clipping intensity was based on removal of growth over forbs when in excess of 30 cm over average forb height.

[3] The serious weedy grasses collectively are basically the same as alien perennial grasses, measured as sum frequency in June 1972.

[4] Percentage basal area.

Table 4. Some soil fertility data at U.W. Arboretum[1].

Site	Strip	No. Samples	pH	Buffer pH	O.M.[2]	Kg/ha (roughly lbs/acre) P	K	Ca	Mg
Wingra Overlook (1/8 ha strips)	1974	3	6.0-6.3	6.6-6.8	25-35	8-10	150-175	2000-2250	800-1100
	1975	1	6.3	6.7	35	17	210	1900	700
Fox Loam	1976	2	6.1-6.2	6.5-6.7	37-70	18	145-270	2000-2800	700-900
Curtis Prairie Miami Loam	West Portion	4	6.1-7.3	6.7	40-50	33-97	180-410	2000-2750	550-1100

[1] Composite soil samples at 0-10 cm depth analysed at U.W. Extension Soil and Plant Lab, August, 1976.

[2] Organic matter

Table 5. Principal prairie seeding responses in three successive 1/8-ha plow-disc-spring-plant contour strips at Wingra Overlook, 1974-1976, as determined August-September 1976[1].

Species[2]	1974 Strip[3] S	1974 Strip[3] F	1974 Strip[3] D	1975 Strip[4] S	1975 Strip[4] F	1975 Strip[4] D	1976 Strip S	1976 Strip F
GRASSES								
Andropogon gerardi	0.3	32.	0.3	5.0	81.	5.5	3.0	P
Andropogon scoparius	1.0	28.	1.4	4.0	40.	1.3	2.0	P
Bouteloua curtipendula	0.1	24.	0.5	0.5	35.	2.3	0.4	P
Elymus canadensis[5]	3.0	32.	1.0	1.5	8.	0.4	3.5	
Panicum virgatum[5]	(2.0)	4.	0.04	2.0	19.	0.5	0.6	P
Sorghastrum nutans[5]	0.3	16.	0.2	6.2	23.	0.4	0.5	
LEGUMES								
Amorpha canescens	0.3	8.	0.2	2.5	P		0.2	
Baptisia leucantha	2.0	62.	1.9	0.5			0.5	
Baptisia leucophaea	0.3	1.6	0.1	0.1	P		0.0	
Lespedeza capitata	(4.0)	16.	0.2	4.0			4.0	P
Petalostemum candidum	0.3	16.	1.5	1.0	8.	0.08	0.3	P
Petalostemum purpureum	0.4	12.	0.4	1.2			0.1	P
COMPOSITES								
Cacalia atriplicifolia	0.3	P		0.06			0.1	
Coreopsis palmata	0.3	20.	2.8	1.0	4.	0.1	0.5	
Echinacea purpurea	0.3			1.0	19.	0.7	0.0	
Heliopsis helianthoides	0.2	16.	0.5	0.8	4.	0.08	1.0	
Kuhnia eupatoroides	(0.5)	28.	7.7	(0.5)	31.	1.3	0.0	
Liatris aspera	(1.2)	8.	0.1	0.3			0.0	
Liatris pycnostachya	(4.0)	20.	0.4	(4.0)	4.	0.04	2.0	
Parthenium integrifolium	(1.0)	12.	0.2	0.0			0.4	
Ratibida pinnata	2.0	92.	5.3	2.5	42.	1.7	1.0	P
Rudbeckia subtomentosa	0.4	4.	0.04	0.1			0.3	
Silphium integrifolium	1.0	8.	0.1	0.1	P		0.06	
Solidago rigida	0.3	P		0.8	P		0.5	
MISC. SPECIES								
Eryngium yuccifolium	0.2	4.	0.04	2.0			0.0	
Phlox pilosa	Tr	8.	0.1	Tr	4.	0.04	0.0	

[1] S column gives pounds of roughly cleaned seed. To calculate kg/ha multiply by 16 (lbs/acre multiply by 4). Parentheses indicate approximate values.

F column gives seedling frequency using 25 random 1 m^2 plots, 60 plots for baptisias in 1974.

D column gives density (no. of seedlings per $meter^2$)

P indicates seedlings present but not counted, Tr indicates trace quantity.

[2] For 74 additional species (including Ceanothus americanus, Sporobolus heterolepis, Pycnanthemum virginianum, Veronicastrum virginicum) mostly in trace quantities, growth was not evident. Of 104 species already present on the 3 strips, 31 were relict prairie species, 22 woody forest species, and 51 weeds and pasture species.

[3] Three sectors sampled equally and results combined.

[4] One 10-cm high mowing on July 25, 1976 to reduce quackgrass and sweet clover invasion.

[5] Species under counted, especially in 1975 strip.

ESTABLISHMENT OF PRAIRIE GRASSES AND FORBS WITH THE USE OF HERBICIDES

Eugene E. Woehler and Mark A. Martin
State of Wisconsin Dept. of Natural Resources
Madison Area Headquarters
3911 Fish Hatchery Road
Madison, Wisconsin 53711

ABSTRACT

Successful establishment of native prairie grass and forbs on large acreages requires agricultural implements and labeled herbicides for seed bed preparation, planting and weed control. Quackgrass (Agropyron repens) was temporarily controlled by the herbicides Roundup* and Casaron* followed by recovery and spread throughout the experimental plots. Four plantings of 7 grass and 24 forb species were made at 10 to 12 day intervals. Dense annual weed growth of foxtails (Setaria spp.) and fall panicums (Panicum spp.) required two clippings in the year of establishment to reduce the competition with the prairie seedlings. Sampling of the vegetation on all plots in 1975 and 1976 indicated establishment of 5 grass species and 14 forb species. Agricultural weeds were the dominant plants. Best results came from the June 4 planting and the poorest from the June 26 planting. Vegetation measurements suggest the prairie species are slowly increasing in relative importance and the annual agricultural weeds declining. Perennial weedy species are persisting, however

KEY WORDS: Quackgrass, herbicides, Roundup, Casaron, seeding dates, prairie establishment

INTRODUCTION

A long range management goal for Wisconsin wildlife areas is to reestablish and manage native or exotic plant communities for optimum wildlife cover and certain human recreational uses. Presently such recreational pursuits as hunting, fishing, trapping, bird watching, cross-country skiing and snowmobiling on designated trails are the primary activities. Conversion of disturbed, eroded agricultural lands well supplied with uncountable exotic weed seeds to native plant communities is considerably more difficult than reseeding a corn field back to common introduced grass and legume species such as brome, timothy, alfalfa or red clover. One of the finest prairie restoration projects accomplished to date in Wisconsin is located at the University of Wisconsin Arboretum. The Arboretum prairie resulted from thousands of man hours in seed collection, planting and transplanting started seedlings and rootstocks of mature clones and subsequent weed control. For a majority of planned restoration projects involving more than one-half acre, the manpower demands to duplicate the University Arboretum could easily exceed availability. Techniques discussed here represent one of several possible approaches to establishment of native prairie species on agricultural fields with a long history of cultivation under a common rotational pattern of corn, oats and hay.

Our experiences with native prairie grasses began in 1965 when six plots, approximately .05 ha in size, were individually seeded to five selections of switchgrass (Panicum virgatum) and one of Indiangrass (Sorghastrum nutans). These plots were located on an alluvial site at the Waterloo Wildlife Area in Dodge and Jefferson Counties.

The 4.5 ha field studied in 1973-76 was typical of the uplands in the vicinity; i.e., rolling topography interspersed with glacial marshes. Soils on this site are moderately fertile silt loams with eroded knolls or hilltops. Prior farming practices included the typical corn, oats and hay rotation. Partly due to erosion considerations, corn is generally planted one year, followed by oats with a forage seeding and hay for two years, occasionally longer. The last crop on the field we treated was corn in 1971. Because of a relatively heavy infestation of quackgrass, this field was left undisturbed until late July 1973, when a local farmer harvested the quackgrass for beef cattle feed in return for plowing the acreage (after herbicide treatment in the spring of 1974). After two growing seasons, quackgrass was the dominant weed with other weedy species not exceeding 5% of the existing vegetation. Mowing had removed all of the early spring growth including the fruiting stems. The subsequent luxuriant fall growth averaged about 20-25 cm in height prior to killing frosts.

Work was done under Pittman-Robertson Project W-141-R, Study 108, entitled, "Experimental Wildlife Management on Farmlands". Our primary interest is the conversion of state-owned lands to improved wildlife cover, chiefly for nesting and brood-rearing purposes.

PROCEDURES

Herbicide Treatments

Casaron. A 0.4 ha section of the dense quackgrass stand was treated with 59 kg Casaron 4-G on December 2, 1973. The granular form herbicide was applied with a cyclone-type applicator sold by the herbicide manufacturer. The intended application rate was 68 kg/ha and the lesser rate represented error in calibration. Applied at 68 kg/ha, Casaron is very effective in killing quackgrass but has the disadvantage of some residual carryover into the next growing season. Since Casaron has only 4% active ingredient (a.i.) this application rate equals 6.73 kg a.i./ha. Because Casaron volatilizes easily, application should be made when air temperatures are no higher than 5° C (40 F). Sod surface should be free of ice or snow and residual vegetation or duff should be limited so the granules reach the soil surface. Uniform coverage is desired. The Casaron plot was not disturbed further until plowing on May 21, 1974.

Roundup. The herbicide, Roundup, was labeled for noncrop use in Wisconsin in 1974. It differs from the systemic Casaron in that best results with Roundup are obtained when applied to vegetation in a rapid growth stage. Application was made on 0.81 ha on May 3, 1974 when new spring growth of quackgrass was in the 4-leaf stage and had reached 25-30 cm in height. A custom designed sprayer with a 6.1 m boom was mounted on I.H. Cub Cadet used in applying the Roundup mixture at the

---

*Brand names for glyphosate and dichlobenil, respectively. Mention of brand name does not represent an endorsement of the product.

rate of 2.24 kg Roundup a.i. in 187 liters water per hectare. The boom was adjusted to .75 cm above soil level with T-jet nozzles (#8003) spaced 50 cm apart on the boom.

Soil Analysis

Core samples of soil (Waterloo silt loam) taken with a soil probe to a depth of 20 cm from five random locations in each of the two plots were analyzed by the State Soils Laboratory for P, K, organic matter, and pH. Results were 95 kg P/ha, 168 kg K/ha, 48 metric tons of organic matter per hectare (approximately two percent by weight), and 6.4 pH. Generally the nutrient level was lower than in other fields checked on the wildlife area but was not deficient enough to warrant additional fertilization.

Post Herbicide Application Response

Casaron. By late April, 1974 the field showed a striping effect. Strips 2.5 m wide were completely killed while adjacent strips of about 1.2 m wide showed some recovery of quackgrass although this new growth was weak and obviously affected by the chemical. Continued slow recovery was detectable until the plot was plowed on May 21.

Roundup. One of the characteristics of weedy species treated with Roundup is the lack of any visual symptoms up to about 3 days following treatment. By the 10th day after application quackgrass was visibly affected, and on the 15th day after treatment the new growth had a brownish-purple coloration suggesting an excellent kill. Other perennial weedy plants such as clovers, dandelions and goldenrods remained green but were distorted.

Seed Bed Preparation

Seed bed preparation by plowing, discing and harrowing, was typical of land being readied for corn planting. Both plots were plowed on May 21, 1974, or 18 days after the Roundup treatment. Because of the dense sod it was necessary to disc the fields twice after plowing to establish a uniform seed bed. Prior to each seeding, the plots were again lightly disced at 10 to 12 day intervals to kill all annual weeds that had germinated. This was also necessary to break up the soil crust caused by rains and to facilitate harrowing after seeding.

Seeding Procedures--Collection, Storage, Mixing and Planting

Seed from the major warm-season grasses, big and little bluestem, Indiangrass, switchgrass and dropseed came from the Wilson State Nursery at Boscobel, where seed from relic stands in southern Wisconsin had been sent in previous years for propagation. We assumed that locally-adapted ecotypes would be preferable. The grass seed was harvested in October and kept in dry, cold storage until planting time. Germination tests were made in the spring at the state seed laboratory in Madison. Twenty-four species of forb seeds were collected in fall 1973 from relic stands in the Waterloo vicinity or were secured from the University of Wisconsin Arboretum. All forb seed was also stored dry at local winter temperatures. None was stratified.

Species selection was based on availability of those species described by Curtis (1959) as modal for mesic and dry-mesic sites. Prior to May 24, the seed allotment was carefully weighed and divided proportionally between the 0.1 ha Casaron plots and the 0.2 ha Roundup plots. Tables 1 and 2 summarize the species and quantity of seed planted per unit area. Each legume species was treated with innoculant prior to mixing with the balance of the grass and forb seed. The seed mixture was hand broadcast on May 24, June 4, June 14 and June 26. After seeding, each plot was dragged with a spike-tooth harrow. Harrowing helps to cover some seed with soil and leaves a good surface to retain moisture from subsequent rains. Fortunately, the late spring and summer rains were well distributed and were close to normal in 1974. Daily precipitation was documented with a rain gauge mounted adjacent to the plots.

Table 3. Monthly precipitation in 1974, the year of establishment

Month	(Centimeters)
May (21-31 only)	1.14
June	11.38
July	8.71
August	9.45
September	2.11
Season total	32.79

Post Seeding Management

Adequate moisture conditions beneficial to germination and establishment of the prairie species also proved a boon to the annual weeds. All plots were mowed on July 18 and again on August 6. The most serious annual weeds were the warm-season grassy annuals, giant and yellow foxtail and fall panicum. Agronomists tend to agree that the high density of these grassy annuals has evolved from persistent use of atrazine which is not particularly effective in controlling these species. Densities of weed seedlings were estimated at 200 to 500/m^2 with lighter densities on plots seeded on June 14 and June 26. Mowing was done with a tractor-mounted rotary mower at 15 to 20 cm. No further effort was made to reduce the weedy competition. In 1975 all plots were left undisturbed except for taking vegetation measurements in late August.

Because we have observed that burning in late April or May will definitely retard the quackgrass development and prevent fruiting, all plots were burned on April 28, 1976 to discriminate against the quackgrass. By late April the new growth of quackgrass averaged about 25 cm. Fire reduced most of the residual vegetation and the new growth of quackgrass and red clover. Except for wild rye, the prairie grasses were generally dormant. Normally, at this latitude we do not anticipate any significant growth of the prairie grasses until mid-May. A majority of the forbs seeded were also dormant when the plots were burned and presumably did not suffer any setback as the result of the fire.

Table 1. Planting rates and relative dominance (%) of prairie species in Casaron treated plots

Species [a]	Pure live seed per m^2	1975 May 24	1975 June 4	1975 June 14	1975 June 26	1976 May 24	1976 June 4	1976 June 14	1976 June 26
Big bluestem *Andropogon gerardi* Vitman	44	0.7	0.7	1.9		6.2	4.5	1.3	0.3
Little bluestem *Schizachyrium scoparium* Michx.	74	1.8	1.9	2.9		0.9	0.8	1.6	
Indiangrass *Sorghastrum nutans* L.	122	3.2	0.5	0.7		2.6	6.9	0.8	
Switchgrass *Panicum virgatum* L.	63		0.2			2.1	2.4		0.3
Canada wild rye *Elymus canadensis* L.	1		0.2						
Sub-total		5.7	3.5	5.5		11.8	14.6	3.7	0.6
	(Estimated)								
Wild Indigo *Baptisia leucantha* T. & G.	2.8								
Baptisia leucophaea Nutt.	0.8								
Unidentified forb				0.8	0.4			T[b]	
Cinquefoil *Potentilla arguta* Pursh.	0.5								
Yellow Cone flower *Ratibida pinnata* (Vent.) Barnh.	3.3								
Whorled milkweed *Asclepias verticillata* L.	0.8	T							
Prairie dock *Silphium terebinthinaceum* Jacq.	0.5								
Purple prairie clover *Petalostemum purpurea* Vent.		5.7	3.5	6.3	0.4	11.8	14.6	3.7	0.6
Annual Mean (grasses only)				3.7			7.7		

[a] Additional species were included in the planting without success, including Prairie dropseed (*Sporobolus heterolepis* A. Gray) 34, Porcupine grass (*Stipa spartea* Trin.) 0.3, Lead plant (*Amorpha canescens* Pursh.) 3.7, Milk-vetch (*Astragalus canadensis* L.) 0.5, Aster (*Aster laevis* L.) 0.5, New Jersey tea (*Ceanothus americanus* L) 0.5, Tickseed (*Coreopsis palmata* Nutt.) 0.3, Shooting star (*Dodecatheon meadii* L.) 7.4, Purple cone flower (*Echinacea pallida* Nutt.) 1.0, Rattlesnake master (*Eryngium yuccifolium* Michx.) 2.0, Bush clover (*Lespedeza capitata* Michx.) 4.0, Gay feather (*Liatris pycnostachya* Michx.) 5.2, White prairie clover (*Petalostemum candidum* Willd.) 0.3 and Stiff goldenrod (*Solidago rigida* L.) 1.5.

[b] T = < 0.1.

Vegetation Measurement

To assess the success of seeding establishment, measurements of the vegetation were taken in August 1975 and 1976 following the technique described by Ohman and Ream (1973). Beginning 4 paces from one corner of each plot, four transects were determined by pacing. Five 0.0004 ha quadrats were selected at about 7 paces apart along each line. In 1975, 20 quadrats were sampled in plots for each planting date and treatment. In 1976, the number of plot measurements taken in the Roundup treatment was increased to 25 while 20 plot measurements were again taken on the Casaron plots.

Relative dominance was determined by the percentage of the canopy of each 0.0004 ha plot occupied by each species. For each seeding date the percent of the 0.0004 ha canopy occupied by all species is totaled. Then percent of canopy covered by each species for all plots in the group is summed and divided by the total for all species.

Table 2. Planting rates and relative dominance (%) of prairie species on Roundup treated plots

Species[a]	Pure live seed per m^2	1975 May 24	1975 June 4	1975 June 14	1975 June 26	1976 May 24	1976 June 4	1976 June 14	1976 June 26
Big bluestem Andropogon gerardi Vitman	44	1.8	T[b]	2.8		2.9	4.8	5.2	2.4
Little bluestem Schizachyrium scoparium	74	0.6	0.3	0.5	0.2	6.6	4.1	3.8	1.3
Indiangrass Sorghastrum nutans L.	122		1.2	1.7		3.3	6.1	1.5	0.1
Switchgrass Panicum virgatum L.	63	0.6	0.6	2.4	T	3.3	1.6	1.7	2.2
Canada wild rye Elymus canadensis L.	1	3.0	1.2		0.2	1.6	0.8	0.3	0.1
Sub-total		6.0	3.3	7.4	0.4	17.7	17.4	12.5	6.1
	(Estimated)								
Wild indigo Baptisia leucantha T. & G.	2.8	T				T		T	
Baptisia leucophaea Nutt.	0.8								
Black-eyed susan Rudbeckia hirta L.	0.0	T	0.9		T				
Unidentified forb			0.9	T					
Cinquefoil Potentilla arguta Pursh.	0.5		T		1.0	0.2	T		0.4
Yellow coneflower Ratibida pinnata (Vent.) Barnh.	3.3			0.2	0.2	0.2	T		0.6
Purple prairie clover Petalostemum purpurea Vent.	37.1			T					
Illinois trefoil Desmodium illinoense Gray	0.5				T			1.1	0.1
Thimbleweed Anemone cylindrica Gray	0.3					T			
Rosinweed Silphium integrifolium Michx.	0.5					T		1.1	0.3
Prairie dock Silphium terebinthinaceum Jacq.	0.5						T	T	T
Whorled milkweed Asclepias verticillata L.	0.8						T		
Compass plant Silphium laciniatum L.	0.8								0.1
Totals		6.0	5.1	7.6	1.6	17.9	17.6	14.7	7.9
Annual Mean (grasses only)			4.3				13.4		

[a] Additional species were included in the planting without success, including Prairie dropseed (Sporobolus heterolepis A. Gray) 34, Porcupine grass (Stipa spartea Trin.) 0.3, Lead plant (Amorpha canescens Pursh.) 3.7, Milk-vetch (Astragalus canadensis L.) 0.5, Aster (Aster laevis L.) 0.5, New Jersey tea (Ceanothus americanus L.) 0.5, Tickseed (Coreopsis palmata Nutt.) 0.3, Shooting star (Dodecatheon meadii L.) 7.4, Purple coneflower (Echinacea pallida Nutt.) 1.0, Rattlesnake master (Eryngium yuccifolium Michx.) 2.0, Bush clover (Lespedeza capitata Michx.) 4.0, Gay feather (Liatris pycnostachya Michx.) 5.2, White prairie clover (Petalostemum candidum Willd.) 0.3 and Stiff goldenrod (Solidago rigida L.) 1.5.

[b] T = < 0.1.

RESULTS AND DISCUSSION

Some prairie grass and a few forb seedlings were noted in all plots in 1974. Mowing twice at 15-20 cm in the year of establishment may be detrimental to the prairie species, but allowing the dense weed competition to mature would probably eliminate any chance of survival. Weedy competition from the foxtails and fall panicum becomes exceedingly severe as these species can germinate and mature at ½ to 1 m or so within 6 weeds. Clipping also stimulates the development of basal adventitious buds of the weedy species which allow seed production and perpetuates the annual weed competition in successive years. These weeds may have some short-term beneficial effects since wintering songbirds, such as slate-colored juncos (Junco hyemalis) and tree sparrows (Spizella arborea) eat the seeds of the annual weedy grasses extensively from early fall through spring unless snow cover prevents availability. Cardinals (Richmondena cardinalis) and mourning doves (Zenaiclura macroura) have also been observed feeding in the prairie reestablishment plots, and it is very probable that many migrant species consume the grassy seeds in fall and again in the spring. To a degree there exists a natural biological control of these serious weedy competitors.

Relative Dominance of the Weedy Species

In many individual plots the percentage of canopy occupied by all species frequently exceeded 100% because of the layering effect. Short or low growing species such as dandelion, white clover and black medic (Scientific names in Tables 1, 2, 4 and 5) often are dominant in the understory and grasses and tall forbs are predominant at higher levels.

Tables 4 and 5 compare the composition of weedy species by each seeding date and herbicide treatment. In three growing seasons, the weedy species showed a rapid turnover, with the annuals declining and the perennials becoming established and increasing in importance. In 1974, the seeding year, foxtails and fall panicum were the dominant species, and despite two clippings produced a seed crop. In 1976, fall panicum had nearly disappeared but some foxtail persisted. It is interesting to note that the foxtails had declined in vigor from robust plants of 0.5 to 1.5 m to small plants 0.2 to 0.3 m tall. Common ragweed exhibited a similar decline in individual plant size. Quackgrass, the original target species increased in both Roundup and Casaron treatments, with a mean relative dominance of 38% for all Roundup groups and 66% for all Casaron groups. The difference in quackgrass dominance between the Casaron and Roundup treatment is attributed to better initial control after the herbicide applications. Red clover, black medic, and white and sweet clover also increased. The balance of the weedy species did not appear to be particularly competitive with the prairie species. Overall, the relative dominance of all weedy species declined in the Roundup treatment from 1975 to 1976 (Table 5). Decline in all weedy species dominance was less in the Casaron treatment. The inevitable persistence of serious weedy competition, despite the use of herbicides, discing, clipping and finally burning, is well illustrated by our results.

Relative Dominance of the Prairie Species

Grasses. The seeding rate for warm season grasses based on pure live seeds (P.L.S.) was believed to be adequate. Without permanent plots and individual seedlings counted in the year of establishment, we cannot be certain of seedling loss from competition or other causes. Germination and emergence of prairie grass seedlings requires between 10 and 15 days under good conditions, while some weedy species appear 3 or 4 days after seeding. Slower emergence and subsequent growth places the prairie grasses at a serious disadvantage with almost all of the weedy species, especially in the year of establishment. After seeding the only alternative for controlling the competition is usually mowing. However, in fields dominated by broad-leafed annuals, some specific herbicides like 2-4,D could be very effective if only prairie grasses were seeded.

Tables 1 and 2 show the relative dominance for each prairie species. In the Casaron treatment, plantings made on May 24 and June 4 showed better establishment in 1976 while the June 14th planting declined in dominance. The June 26 seeding was essentially a failure. The cause of the failure was not certain except that seedling survival may have been lowered by the shorter growing season resulting in the lack of a good root system. Neither prairie dropseed nor needle grass has appeared in any plot on the Casaron or Roundup treatments. Dropseed was planted in sufficient quantity that some plants should have been evident either in the plots or observed in the fields. Needlegrass was planted in small amounts and its matted seed clumps, caused by the persistent twisting awns prevented a good distribution of the seed. Canada rye only appeared in one seeding in the Casaron treatment but occurred in all Roundup groups (Tables 1 and 2).

Prairie grass relative dominance was decidedly better in all Roundup plots than the Casaron counterparts. Table 1 shows an improved and superior establishment for the May 24 and June 4 seedling. This suggests that earlier plantings tended to be more successful than later seeding in both herbicide treatments. Relative dominance showed a two-fold increase in the Casaron treatment and a three-fold increase in the Roundup treatment between 1975 and 1976. A preliminary judgement would be that these species can compete with the weedy species with the increase in dominance probably due to the spread of individual clones. Some fruiting occurred in 1975 and increased in 1976 as clones began to mature. In 1976 fruiting culms on most clones, especially big bluestem and Indiangrass were shorter, about 1 m average compared to expected 1.5 m height or taller noted in most seasons. A rainfall deficit beginning in May and continuing throughout the growing season may have contributed to the general short stature of the prairie grasses.

Prairie Forbs

Twelve of the 24 species of forbs appeared in the measured plots in 1976 and two additional species were noted outside of the measured plots. Black-eyed Susan was not planted but appeared in the Roundup treatment. Locally this is a common species along undisturbed roadsides and fence rows. Tables 1 and 2 summarize the relative dominance of the prairie forbs. Maximum dominance by forbs was recorded for the June 14th Roundup seeding in 1976. The June 14th and June 26th forb plantings appeared to be slightly better established. All three Silphium species and two Baptisia species require cold and moist stratification to break dormancy, and these species did not germinate until the spring of 1975. Shooting star and rattlesnake master were planted in quantity but have not appeared in either treatment area. Seed of both

Table 4. Relative dominance (%) of weedy species in Casaron-treated plots

Species	1975				1976			
	May 24	June 4	June 14	June 26	May 24	June 4	June 14	June 26
Quackgrass Agropyron repens (L.) Beauv.	48	57	56	46	62	63	77	63
Common ragweed Ambrosia artemisiifolia L.	31	22	24	19	13	11	11	7
Foxtails Setaria faberii Herrm. Setaria lutescens (Weigel) Hubb.	4	4	4	9	2	5	2	2
Marestail Erigeron canadensis L.				1				1
Dandelion Taraxacum officinale Weber	1							1
Red clover Trifolium pratense var. sativum (Mill.) Schreb.			1	2	2	1	2	8
White cockle Lychnis alba Mill.					1			2
Bindweed Polygonum convolvulus L.								
Smartweeds Polygonum pennsylvanicum L.	1		1					
Plantain Plantago rugelii Dcne.					4	2		
White clover Trifolium repens L.								
Fall panicum Panicum capillare L. Panicum dichotomiflorum Michx.		2	6	3				
Oxalis Oxalis stricta L.		1						
Black medic Medicago lupulina L.			5	19			3	14
Crabgrass Digitaria sanguinalis (L.) Scop.	8	8						
Aster Aster pilosus Willd.	1				3	2		
Daisy fleabane Erigeron strigosus Muhl.								1
Other	1	2	1	1	1	1	1	
Total Weed Dominance	94	96	98	99	88	85	96	99
Annual Mean		97				92		

Table 5. Relative dominance (%) of weedy species in Roundup-treated plots

Species	1975				1976			
	May 24	June 4	June 14	June 26	May 24	June 4	June 14	June 26
Quackgrass *Agropyron repens* (L.) Beauv.	7	36	41	51	25	34	48	46
Common ragweed *Ambrosia artemisiifolia* L.	45	36	41	24	12	22	19	30
Foxtails *Setaria faberii* Herrm. *Setaria lutescens* (Weigel) Hubb.	16	10	2	2	1	4		2
Marestail *Erigeron canadensis* L.	11	3	1		4	2		1
White cockle *Lychnis alba* Mill.	1	2	1	10	6	4	2	6
Red clover *Trifolium pratense* var. *sativum* (Mill.) Schreb.	2	2			11	7	3	2
Plantain *Plantago rugelii* Dcne.			4	7			3	3
Dandelion *Taraxacum officinale* Weber	6	3		1	8	4	1	
Sweet and white clover *Melilotus officinalis* (L.) Lam. *Trifolium repens* L.	1	1			10		3	
Black medic *Medicago lupulina* L.							6	
Smartweeds *Polygonum pennsylvanicum* L.	1		2	1			1	
Aster *Aster pilosus* Willd.					3	2		
Bull thistle *Cirsium vulgare* Savi.	3				1			
Fall panicum *Panicum capillare* L. *Panicum dichotomiflorum* Michx.	1							
Lambsquarters *Chenopodium album* L.	2							
Other	1	2			1	2		1
Total Weed Dominance	97	93	92	98	82	82	86	91
Annual Mean	95				85			

species appeared potentially sound and viable. Gross examination of all forb seed collected suggested a probable high incidence of poor seed in purple prairie clover and gay feather resulting from insect infestation and undeveloped embryos. Yellow coneflower, black-eyed Susan, compass plant, rosin weed, prairie dock, whorled milkweed and tick trefoil appear most frequently in local relict stands so their prominence in seeded plots is not surprising. Several species consisting of relatively few plants may also be established but have not been observed to date.

SUMMARY

The herbicides Casaron and Roundup initially controlled quackgrass to allow establishment of the prairie grasses and forbs. Recovery from an incomplete kill of rhizomes was rapid, and quackgrass is again the most dominant single species. In 1976, quackgrass had a relative dominance of 38% in the Roundup treatment and 66% in the Casaron treatment. Despite the severe weedy competition five prairie grasses and 12 prairie forbs have established and have shown an increase in relative dominance between 1975 and 1976. Earliest seedings made on May 24 and June 4 had a better establishment over the plots seeded on June 14 and June 26. Improvement in establishment success might be achieved if quackgrass was not the primary weed problem. A minimum of three growing seasons is needed before a recognizable prairie-like plant community can be expected.

LITERATURE CITED

Curtis, John T. 1959. Vegetation of Wisconsin. University of Wisconsin Press. Madison, Wisconsin.

Ohmann, Lewis F. and Robert R. Ream. 1971. Wilderness Ecology. U.S.D.A. Forest Service Research Paper NC-49. 14 p.

Ohmann, Lewis F. 1973. Vegetation Data Collection in Temperate Forest Research Natural Areas. U.S.D.A. Forest Service Research Paper NC-92. 35 p.

ACKNOWLEDGEMENTS

Dr. Thomas Armstrong, product development representative of Monsanto Chemical Company provided the Roundup for experimental use. Drs. L. R. Binning and R. A. Newman, herbicide and grass extension specialists, and graduate assistant Bruce Michaelis of the University of Wisconsin-Madison, Department of Horticulture, provided the sprayer unit and supervised the application of Roundup. The University of Wisconsin Arboretum, under the direction of Dr. James Zimmerman, supervised the annual collection by numerous Madison and vicinity school groups of the many native prairie grass and forb seeds from the Curtis and Greene Prairies which supplemented our collection of forb seed. The University of Wisconsin-Madison, Department of Agronomy made available their seed cleaning facilities.

Wilson State Nursery at Boscobel, under the supervision of R. A. Camp, produced seed of the primary warm season native grasses. Seed was originally collected in 1971 from relict stands in the Madison vicinity by personnel from the University of Wisconsin-Madison, Department of Botany, and Arboretum staff and members of the Soil Conservation Service and Department of Natural Resources. Walter Jacobson, senior landscape architect, DNR offered many helpful suggestions based on his experience in developing the first large scale planting of warm season grasses at Lake Kegonsa State Park in 1967. Dr. James March, Farm Wildlife Group Leader, Bureau of Research, DNR, provided editorial assistance.

THE "DO'S AND DON'TS" OF PRAIRIE RESTORATION

Peter Schramm

Knox College
Galesburg, Illinois 61401

ABSTRACT

Based on ten years of prairie restoration efforts on the Knox College Biological Field Station located in Knox County, west central Illinois, this paper reviews the various procedures used to plant and establish prairie. The two most important variables affecting restoration are weed seeds present, and prompt germination of a high percentage of the grass and forb seeds planted. Suggestions on how to control these variables are presented. A variety of successful planting methods may be used. There is no such thing as instant prairie; therefore, the installment plan is recommended, trying different kinds of plantings over several years. Forb enrichment of existing stands, and the ecotype problem are discussed. Quality prairie plants are defined, and a list of grasses and forbs is presented indicating quality, competitive ability, ease of restoration, seed conditioning, habitat preference, time of blooming and showiness.

INTRODUCTION

During the First Midwest Prairie Conference held in 1968, it became obvious there was much we did not know about prairie restoration. Many eager new prairie enthusiasts wanted to know the best way to get prairie started, but only a few could offer concrete suggestions on how to propagate the various species and achieve some semblance of a prairie community. In the years that followed there was much trial, error, and variable success in prairie restoration. New people and projects were trying to establish prairie, going about it in their own way, and not profiting from the mistakes of others. The same method tried in two different places or in two different years, or by two different persons yielded different results. The problem became one of determining the most important variables and controlling them to achieve a successful planting.

Based on ten years of restoration efforts on the Knox College Biological Field Station located in Knox County, west central Illinois, this paper will attempt to pinpoint and emphasize the major variables in prairie restoration, point out the "Do's and Don'ts" of planting prairie, review the various procedures and methods that have worked, and list the various prairie species with regard to their quality, ease of establishment and competitive abilities. It will also attempt to up-date previous papers by this author based on the Knox project (Schramm 1970; 1972).

THE TWO MAJOR VARIABLES IN PRAIRIE RESTORATION

There are two major variables in prairie restoration that will influence the success of the planting; weed seed present in the planting site, and degree of prompt germination of both grass and forb seed.

The first variable, that of weed seed, is very unpredictable and more difficult to deal with if a real weed problem exists. The second variable, that of germination and viability of seed, can be determined prior to planting. Prompt germination can be enhanced by cold-damp conditioning (or stratification), scarification, and other kinds of treatments which condition seed and break dormancy or prevent the seed from ever becoming dormant.

These two variables, and how to deal with them, will be discussed separately in some detail.

The Weed Seed Variable and Weed Competition

The amount of weed seed present in the planting site is perhaps the most variable and unpredictable factor in prairie restoration. There is no way to predict with certainty the amount of weed competition that will be present during the first few years of restoration. One can generalize, however, and state that fallow fields and recently farmed fields result in weedier plantings than the field of perennial pasture grass sod. But again, this may not always be the case. A plot of bluegrass sod (*Poa pratensis*) on the Knox Field Station, Fall-plowed and planted late the following Spring, resulted in a remarkably weed-free planting. Another nearby site of orchard grass sod (*Dactylis glomerata*) Fall-plowed and late Spring planted was very weedy with a heavy growth of the annuals velvet-leaf (*Abutilon theophrasti*) and witch grass (*Panicum capillare*). Very much depends on the weed seeds that are lying dormant in a particular site irregardless of the kind of plant cover present.

Solutions to the Weed Problem

There are four things that can be done to alleviate or reduce the weed problem:

1. Late Planting. Plant as late as possible, but before the mid-part of the growing season. In western Illinois the ideal time is the first two weeks in June. This late planting date allows time for the site to be lightly and shallowly cultivated to eliminate weeds as they germinate. Weed seeds begin to germinate as soon as the soil warms up in March. Late planting allows two to three months of weed germination, shallow cultivation, and weed removal. Do not deep cultivate as this only brings up more weed seed. Usually a thorough discing in March levels the Fall-plowed site, and then shallow discing or harrowing at two to three-week intervals eliminates much of the problem.

The only danger to late planting is that in a particularly dry season the project might not get the necessary precipitation to germinate the seeds. However, if the seeds have been handled correctly, they will be on the verge of germination and it will take very little soil moisture to get things going. Prairie plants are remarkable in that they "grow down" the first year not up (Wilson 1970), and the seedlings quickly send down roots to considerable soil depths during the first few weeks of growth.

The one exception to a later planting date is in certain kinds of strip-mine sites of heavy and water impervious substrates. Here an earlier planting is necessary to utilize the more abundant Spring precipitation. The lighter mid-summer rains may germinate the late planting but not be adequate enough to penetrate and sustain the important early growth and root penetration. Fresh stripmine sites are usually devoid of weed seed and no weed problem occurs that first season.

Fall plantings have been tried by other projects with varying degrees of success and results, but this author, along with others, recommends against such procedures because of possible Fall germination and frost-heave, loss of seed to rodents and other wildlife over the Winter, and especially because of the early starts the weeds will get over the germinating prairie plants the following Spring (Schulenberg 1970).

2. Mowing. If there is a real weed problem the first season, particularly of broad-leafed forbs such as velvet leaf or lamb's quarter, these should be mowed in late July with a rotary-type mower to prevent heavy shading of the prairie plants and reduce the competitive vigor of the weeds. This should be done when the weeds are two to three feet in height, setting the mower at about twelve inches so as not to mow off the tops of the shorter prairie plants. If the season is particularly wet, a second mowing may be called for, but one usually suffices. A weed growth of annual grasses such as foxtail (*Setaria* sp.) or witchgrass is usually not too serious and will provide needed fuel for the first burn the following Spring. The prairie plants remaining small the first season do not provide much fuel.

3. Fire. Burning is a third procedure that can be carried out to reduce weeds and increase prairie plant growth. As mentioned above, first year weed cover may provide the necessary fuel, or the prairie grasses themselves may contribute to a burn. Burning is best done in the Spring even in mature prairies so that cover for wildlife is available during the Fall and Winter. The best time to burn in Illinois is from mid-March to the second week in April. In some years an earlier burn may be possible, but burning after mid-April may disrupt nesting birds and cause mortality to reptiles. The important point on burning is that one must be poised and ready to burn at the proper moment as usually there is only one chance for a good burn during this early Spring period.

Fire reduces the vigor of the cool-season weedy forbs and grasses such as bluegrass, if such perennials persist or show up in the site. In the later stages of restoration, fire prevents or reduces the invasion of woody plants into the prairie site. As for true prairie plants, they thrive under a burning regime. Grassland communities have evolved with fire as an omnipresent factor, and prairie seedlings of all kinds, both grasses and forbs, respond remarkably to regular annual Spring burning during the first few years of restoration. In small sites dry straw may be scattered on the planting to achieve fuel for a first year burn. In the ensuing years, the prairie plants themselves provide all the fuel that is needed.

4. Patience. The final approach to weeds in a restoration project is one of wait and have patience regardless of how weedy the project appears the first few years. Never plow up a planting. Even the weediest sites improve with age. It is difficult and sometimes impossible to find the prairie plants amongst the weed growth, but they do show up in time. Some of our weediest plantings on the Field Station have turned out to be quite impressive patches of prairie with new forbs showing up even eight to ten years after the initial planting. These forbs have not necessarily germinated later but, rather, have finally become evident from their size and flowering -- on the other hand, unscarified seed such as the legumes may lie dormant for several years before germinating.

Seed Conditioning, Viability and Germination

The other major variable in prairie restoration, and perhaps the most importnat factor for a successful prairie planting is the viability and rapid germination of grass and forb seed. Two factors influence seed viability. The seed may not maturate properly due to poor conditions during the growing season or during the final ripening time, or, what may happen more frequently, insects may damage the seed prior to or even after harvest. The field conditions for ripening and the insect damage prior to harvest cannot be controlled. Insect damage after harvest can be controlled by brief fumagation with chloroform, paradichlorobenzene, or other suitable fumigants. This is necessary mainly with forb seed and, particularly, with species of *Liatris*, *Ceanothus*, *Eryngium* and *Baptisia*.

Proper handling and conditioning of the seed after harvest is the most important factor determining a successful planting. Some seeds such as the legumes need no dampening, but may be stored dry until planting time. They must be scarified, however, for prompt germination and inoculated for proper growth. This scarification is best accomplished by placing small amounts of seed on a sheet of fine-to-medium sandpaper or on a concrete floor and very lightly sanding with a sanding block. Other seeds such as the grasses and many of the forbs should be cold-damp conditioned.

Grass Seed Conditioning

Prairie grass seed, at least the Illinois ecotypes, must have cold-damp conditioning for maximum and rapid germination. Seed harvested and left dry even though subjected to cold or freezing temperatures may, in six to eight months (September to May), lose 90% of its viability. In contrast, grass seed harvested in September and immediately stored just above freezing with its own moisture content, or with slight additional dampening, will yield 90% germination the following Spring. The best procedure is to dampen slightly (2 quarts H_2O per 20 lbs. seed) and store immediately at just above freezing temperatures (34°F) in covered plastic containers or bags. Seed should be aerated once every month or so to reduce mold in the closed containers. This is easily done by emptying seed from one container to another or by opening bags briefly and turning contents. Just before planting time, the seed is removed from cold storage, spread out on a dry floor in a 2"-3" layer and dried for a day or so. Use of a large window fan moving air above the seed, plus occasional raking and turning, will hasten drying. Drying is necessary if a drill is to be used for planting and will also facilitate broadcasting the seed by hand or by small mechanical seeder. Drying should not be prolonged or else a deep dormancy may set in.

Forb Seed Conditioning

Most forbs, including the Spring-blooming species

(Zimmerman 1972, Threfall 1972) should be dampened immediately after harvest, stored in plastic bags and placed in cold storage at the same just-above-freezing temperature. No additional material such as vermiculite or sand is necessary. This simplifies the process and the chaff associated with most seeds is sufficient to hold moisture and separate the seed. Like the grass seed the forbs are brought out of cold storage just before they are planted. If they are to be mixed in with the grass seed, it is not necessary to dry the forbs. Just stir them into the dried, fluffy grass seed. We do this right in the drill hoppers after they are loaded with dry grass seed. Dry grass and forb seed may be held for one to two months without too much loss of viability, but the sooner they go into cold-damp storage the better.

PLANTING METHOD

Prairie may be planted in any of a number of ways with reasonably good results. As we have emphasized above, reduced weed competition and prompt seed germination determines the success of a planting far more than the planting methods used. Prairie may be drilled (Schramm 1972, Wilson 1970), hand broadcast (Schramm 1970) or run through small seeders or any mechanical device which will give an even scattering of seed over the planting site. Methods that do not drill the seed into the ground call for raking or harrowing followed by rolling or tamping to set the seed into the ground. If properly raked or harrowed, follow-up rains may be enough to set the seed into the ground surface for proper seedling establishment. The whole process for both grass and forbs is not unlike planting a lawn. Hydroseeding is another method that has been proven successful in prairie establishment (Brakeman 1975), reinforcing the notion that any of a number of planting methods will work. Drilled prairies have an initial row appearance to them but this becomes less noticeable in just a few years. In the smaller projects the hand-planting of seedlings at evenly spaced intervals facilitates hand weeding and hoeing (Schulenberg 1970) and the results of such labor may be spectacular. The layout and planting of spaced seedlings is greatly facilitated by the use of a planting board with evenly spaced bolts protruding at the chosen interval to mark the holes that receive the hand-planted seedlings. In the absence of competition from surrounding weeds or other prairie species the grasses and forbs will put on remarkable growth the first season and may even bloom in the first or second year. Such projects are labors of love. Persistent weeding for up to two years is very much worth the effort but can only be done on a small scale. Hand planting is one of the best ways to establish the very competition-sensitive species such as butterfly weed, (*Asclepias tuberosa*), prairie dropseed (*Sporobolus heterolepis*) and Culver's root (*Veronicastrum virginicum*).

THE INSTALLMENT PLAN IN PRAIRIE RESTORATION

One of the major considerations in planning a prairie restoration project is the timetable involved and the size of the area to be planted in any given year. Some key points need to be mentioned here.

There is no such thing as instant prairie. I have observed too often the rushed project results in failure or at most a very poor stand. It takes time to prepare a site, gather seed, condition it properly, arrange for equipment and plan the details that ensure success. Also, there is nothing like experience to enhance results. Therefore, we recommend the installment plan approach to planting prairie. Plans for a restoration project should start a year in advance of the first planting. The total site should be divided into several years plantings. The reasons for this are manifold: weed seed variability from year to year and site to site; seed viability from year to year; seed availability from year to year (we obtain some species one year and others another year; rarely do we get all the species we want for a particular year's planting), and finally, there is no substitute for experience. The experience gained in the initial plantings increases the probability of the success of later plantings and the overall project. With the installment approach one can try several different methods, and a more interesting and diverse prairie will result.

COMPOSITION, DENSITY AND COMPETITION

There is a definite relationship between competition and the resultant degree of seedling establishment and the composition and density of the species planted. In other words, the prairie plants are competing with themselves as well as the weeds. There are different kinds of restored prairies that can be achieved depending on what is planted with what, and at what seeding rate or density.

We all know there are different kinds of prairies represented in the few remaining remnants that we have as models. Some are very grass-dominated with forbs present but less evident. Others are amazing in their forb diversity and abundance, with the grasses present, but presenting a much lower profile resulting from competition from the numerous forbs. There is still much debate as to which model truly represents the pristine, original prairie. Perhaps the true picture is one of a mosaic of the two types depending on local heavy use by the larger grazing ungulates. Be that as it may, the restorationist must decide what the end product is to be like and plant accordingly.

The Grass Planting

Some projects want a grass-dominated prairie quickly established for a grassland effect for public viewing or erosion control. Such a prairie can be achieved with a denser seeding rate of species such as Big Bluestem (*Andropogon gerardi*) or Indian Grass (*Sorghastrum nutans*) or a mix of the two, at from 25 to as high as 50 pounds per acre seeding rate. Some of the more competitive forbs such as the *Silphiums*, coneflowers, goldenrods, and sunflowers can be planted at the same time and will also establish in spite of the dense grass stand. The result is an impressive grass stand in two to three years, with large, prominent composite forbs blooming a year or so later than the grasses. Such stands can be enriched at a later time, at least with some species of prairie legumes (see forb enrichment). With burning management the grass prairie quickly becomes remarkably free of weeds.

The Forb Planting

Still another approach is that of the forb planting. This involves a very dense planting (as much seed as you can get your hands on, no rate is too high) of high quality prairie forbs (legumes, less weedy composites, etc.) all planted in a small area. A light sprinkling of grasses may be planted at the same time or scratched in, a year or so later. The result is usually a rather weedy plot for several years. Then the dense forbs come into their own and give the appearance of an impressive and showy stand more like some of our truly quality remnants.

The Compromise or Mixed Planting

The third approach is one of compromise between the above two extremes: eight to twenty pounds of grass seed per acre with forb seed spread over a larger area and seeded directly with the grasses. This compromise is typical of many restoration projects. The installment approach allows for all three methods to be tried.

Reemphasizing a final point - the denser the grass, the less weeds, the quicker visual results, but sometimes the fewer the forbs due to competition with the prairie grasses. Of course the hand planting of spaced seedlings, discussed earlier, allows complete control of composition and density.

FORB ENRICHMENT

Can an established stand of prairie be enriched by more forbs at a later time? Much work still needs to be done in this area, but some preliminary results are emerging. One initial experiment on the Knox Field Station indicated positive results with some legume species.

During late April 1969, after a burn had eliminated all litter and standing dead, a harrow was dragged round and round over the same circular swath in a well established, 14-year old stand dominated by Big Bluestem. Some Indian Grass and Little Bluestem (Andropogon scoparius) were present in spots, as was the weedy composite Solidago altissima. After numerous passes over the circular swath, the surface of the soil between the grass plants showed some pulverizing effect and a kind of very shallow seedbed was established. Beneath the surface was a dense, wirelike network of grass roots. Into this harrowed area a legume seed mixture of Petalostemum purpureum, P. candidum, Baptisia leucantha and Amorpha canescens was densely hand broadcast and rolled in with a large lawn roller. Some of these legumes bloomed three years later, and at the present time, this area presents some well established and persisting legumes, adding great improvement to this stand of prairie. The prairie clovers are particularly evident. Such a procedure would not work with the more competition-sensitive species and would be merely a waste of seed.

Another forb-enrichment process that has been tried with variable success in the Knox project consists of setting out seedlings of various forbs species in planting holes cut into existing prairie grass sod. Various tools such as trowels, narrow spades, and bulb-planting tools have been used. These seedlings experience considerable mortality from deer and rabbits attracted to the disturbed site, or from drought conditions caused by moisture competition with the massive amounts of grass roots the seedlings are surrounded by. For successful establishment this procedure calls for fencing protection and watering the seedlings for several weeks, until establishment is assured.

Much work still needs to be done in the area of forb enrichment.

THE ECOTYPE PROBLEM

There has been much discussion and voiced concern in recent years among prairie people about the use of non-native ecotypes of prairie grasses and forbs. This author was himself involved in a planting of commercial strains of grass species obtained from Nebraska in 1970 (Schramm 1972). The concern about this practice began to emerge at the time of the Second Midwest Prairie Conference at Madison, Wisconsin, and flourished during the third conference at Manhattan, Kansas in 1972 (Schwarzmeier 1973). Since that time there has been a steadily increasing effort on the part of prairie restorationists to obtain local seeds of grasses and forbs, rather than send away for commercially available strains from distant points of origin. Most of these commercial strains of prairie grass originated in the west-central and southern portions of the great plains and were developed at plant materials centers in response to the need of reseeding range land deteriorated by overgrazing and drought years.

There are several important reasons for using locally adapted ecotypes. The meaning of the word restoration implies bringing back what was originally present. In many areas of the Middlewest the local ecotypes of native grasses and prairie forbs are extinct. One of the responsibilities of restoration projects is, where possible, to search out local seed sources and reestablish these small gene pools in the sanctuary of the restoration site. This is what we mean by restoration. The preservation of the diversity of organic evolution and the complete ecosystem is one of the issues involved.

It is well documented in many plant species including a number of prairie species that various ecotypes differ from one another in a variety of ways including adaptive abilities, flowering time, growth responses, and physical characteristics such as height at maturity. It makes common sense that if one is attempting to restore a big bluestem prairie in central Illinois, a shorter ecotype from western Kansas would be rather inappropriate.

It has been suggested by some that "wild-type" strains of grasses are not as vigorous or not vigorous enough to establish good persisting stands, compared to the commercial strains. This is not in accord with the results of numerous restorations including the Knox project where local ecotypes, if handled and planted properly, establish excellent stands.

Finally, there is the problem of the too vigorous commercial ecotype. Blackwell Switchgrass (Panicum virgatum) is the case in point. This variety was used in a drilled planting mixed with other grass species and a variety of forbs (Schramm 1972). In follow-up studies on this planting it was determined that the other grass species and forbs germinated and established for a short period but were totally overwhelmed and out-competed by the Switchgrass early the second year.

All of the above points are ample reason for being purist when it comes to seed sources. Midwest ecotypes are becoming increasingly available now from several Illinois sources.

How far away should one go for seed? As a rule of thumb 200 miles north (or south) and 150 miles east (or west), but one has to use judgment here in relation to transition across areas of significant climatic change. As an example, a central Illinois project could use eastern Iowa seed but should hesitate to use seed from western Iowa.

The most discouraging aspect to the ecotype problem is the continuing practice of large-scale commercial plantings on roadways and industrial sites that must have large amounts of prairie grass seed here and now and end up sending off to the western producers for the commerical varieties.

FIELD OCCURRENCE OF QUALITY FORBS

Most of us have observed at one time or another the occurrence of a quality prairie species in abundance in some gravelly or poor soil area along a country road, a railroad embankment, or on some remote and eroded hillside. The occurrence of butterfly weed (Asclepias tuberosa), prairie dock (Silphium terebinthinaceum), and cream false indigo (Baptisia leucophea) along gravelly roadside banks in the Missouri Ozarks and species of Liatris in poor soil areas along railroad right-of-ways, are examples of this. Such occurrences are best explained by the remarkable ability of prairie plants to send down deep roots to obtain required moisture and nutrients. They get established in the absence of competition from the common Eurasian weeds which simply cannot do well in such a harsh site. This points up the fact that many of our prairie species are admirably suited to establishment in deteriorated sites that need reclamation and plant cover. It also points up the role of competition in the establishment of some of the more "difficult" prairie forbs.

QUALITY PRAIRIE PLANTS

As one visits various prairie remnants and studies the composition of prairie species one begins to get an impression of what constitutes a high grade prairie remnant and what constitutes a degraded one. From the various assemblages of prairie forbs certain species emerge as high quality plants.

How can we determine what species are really high quality? By studying and comparing the least disturbed prairie remnants with the more disturbed prairie sites one can get a comparative basis on which to judge the quality of a particular prairie species. A high quality prairie plant can be defined by the following characteristics:

1. Found in abundance in the least disturbed sites.
2. Found only in low numbers or absent in degraded and disturbed prairies.
3. Is not weedy or aggressive; does not readily invade new sites.
4. Appears to be climax, or, stated another way, is an important self-reproducing component of a mature, well developed and diverse prairie community.
5. May be recognized by the company it keeps; that is; it is found in association with other high quality species.
6. May be difficult to restore, indicating perhaps the need for the special condition of the mature prairie community for establishment.

It is probably evident from the above that the term "quality" is closely associated with the climax, mature and well developed prairie.

Our studies in restoration have not addressed themselves to gathering quantitative data to document just what species are high quality, but we are ready to indicate by the following list, based on our experience and the above mentioned criteria, just what we think are high quality and lower quality species. We are doing this because we have observed and are concerned with a lack of discretion with regards to forbs which are referred to as prairie species or quality prairie species. Not all forbs in a prairie remnant can necessarily be pegged with a high or low quality designation, but certainly some of them can. And certain forbs do not belong in a prairie at all and should not be planted or even considered if we are really talking about prairie restoration.

Another key point to be considered in choice of species is geographical distribution. The restorationist should become familiar with the composition of local remnants and the recorded distributions of the species to be used. For example, two very well known species, pasque flower (Anemone patens) and prairie smoke (Geum triflorum) are highly desirable in restorations in Iowa, Wisconsin and northern Illinois but are completely out of place and do not belong in restorations located in central Illinois. True prairie restoration calls for an informed approach and a great deal of discretion.

PROBLEM SPECIES

Certain species can cause real problems and simply should not be planted in prairie restorations. Helianthus mollis, Downy (Ashy) Sunflower: A number of the species of Helianthus are known to be allelopathic (Rice 1967, Wilson 1970) and H. mollis has turned out to be extremely so. In several restoration sites on the Knox Field Station this species is spreading rapidly, developing sterile clones six to twelve feet in diameter and in the older clones is killing itself out in the center, forming a kind of toxic fairy ring with the center becoming devoid of any plant life. Helianthus grosseserratus, Sawtooth Sunflower: Large, coarse sunflower, very aggressively spreading by rhizomes and also forming sterile clones. Solidago altissima - canadensis complex, Tall Goldenrod: Very weedy composite that will persist in a restored prairie for a number of years even when regularly burned. After fifteen years it will gradually decrease as burning continues and the restored prairie develops. This species should be eliminated from the site by plowing prior to any initial planting.

SPECIES APPROPRIATE FOR MIDWESTERN RESTORATION

The following list does not pretend to be complete with regard to all prairie species that occur in the tall-grass area, but it does include those species that are considered to be important in prairie restoration. It is presented as an effort at making qualitative distinctions between the more frequently encountered species. In addition, competitive ability, ease of restoration, seed conditioning, habitat with regard to moisture, flowering time, and showiness are also indicated. Restoration notes are offered as a general guide. For additional details on propagation see Rock (1974).

The grasses are discussed separately in a little greater detail with regard to the above points.

Prairie grasses

Andropogon gerardi, Big Bluestem: This is the high quality, showy dominant grass of the upland mesic, medium moist prairie. Competitive, but not aggressively so, it is easy to restore, with cold-damp treatment soon after harvest. Blooms mid to late summer, ripens by September.

Sorghastrum nutans, Indian Grass: The other important and showy co-dominant of the upland mesic prairie but grades into slightly dryer sites including lower portions of hill prairies. Easy to restore with all methods. Handle the same as Big Bluestem. Same flowering and ripening time.

Andropogon scoparius, Little Bluestem: A lower profile, very showy (maroon in Fall) bunch-grass dominant of hill prairies and the dominant grass of midwestern sand prairies. Restores easily and does well in any kind of restoration sites. Handle same as the above.

Sporobolus heterolepis, Prairie Dropseed: A super-high quality prairie grass of great beauty, bunch-grass in character, highly desirable in any prairie planting but very difficult to restore in the mixed, drilled or broadcast planting. Best established by setting out seedlings. Seasonal aspect like the above. This species ranges from medium moist to dryer swells of mesic uplands. Apparently very competition-sensitive at the germination to tiny seedling stage, but will persist forever once established. Moderate height.

The above mentioned species I consider the Big 4 of midwestern prairie restoration.

Panicum virgatum, Prairie Switch Grass: a handsome species of mid-height, but a little of this species goes a long way; tends to grow in pure, forbless stands. It was definitely part of the original mesic to lowland prairies occurring naturally in the swales and edges of Spartina bottomland prairie. However, will grow almost anywhere it is planted, is very competitive and will persist. Go easy! (Recall the discussion of the commercial strain, Blackwell Switch Grass.)

Spartina pectinata, Prairie Cord Grass: The tall profile, dominant grass of the bottomland prairie and wet swales of the upland mesic. Tends to grow in pure, forbless stands. In the proper sites will spread aggressively by rhizomes. Restoration by seed unpredictable but easy from plugs of sod. Of limited use in restoration because of its competitive nature and rhizomaceous spreading.

Bouteloua curtipendula, Side Oats Grama: A hill prairie species found occasionally in sandy loam but not important in the true sand prairie. More of a cool season species, this low profile grass lends interest to a dry prairie planting and is easily restored in a variety of sites.

Stipa spartea, Porcupine Grass: Occurs naturally on dryer swells of the mesic prairie, and, like the above, adds interest to the diverse prairie planting. Different in that it matures and ripens in early summer.

Less important species of grasses that have high fidelity with regard to their occurrence in prairies, and which should be included in the planting of the purist in the Illinois area include: Panicum leibergii, Prairie Panic Grass: A high quality species of mesic to dryer sites; low in profile but adds interest to the more complete restoration planting. Panicum oligosanthes schribnerianum, Schribner's Panic Grass: Another panic grass species found in sand prairies and occasionally in black-soil mesic prairie. Koeleria cristata, June Grass: A sand prairie associate of Andropogon scoparius, of medium quality and medium profile.

The short-grass species that occur commonly further west, are not included here for the midwest restoration but are quite appropriate in the great plains regions of lower rainfall.

Prairie Forbs	Quality	Competitive Ability	Ease of Conditioning	Seed Conditioning	Habitat	Flowering	Showiness
**Allium cernuum Nodding Wild Onion	High	Moderate	Medium	Cold-damp	Mesic	Mid to Late Summer	Low-attractive
**Amorpha canescens Lead Plant	Very high!	Moderate	Forb planting or by seedlings	Scarify	Mesic to Dry	Mid-Summer	Very Showy
Anemone cylindrica Prairie Anemone	Very high!	Moderate	Forb planting or by seedlings	Cold-damp	Mesic to Dry	Early Summer	Moderate
Anemone patens Pasque Flower	High	Moderate	Forb planting or by seedlings	Brief cold-damp	Dry	Late Spring	Low Showy
Asclepias hirtella Tall Green Milkweed	High	Low	Set out seedlings	Short cold-damp	Mesic to Moist	Summer	Subtle-taller
Asclepias sullivantii Sullivant's Milkweed	High	Low	Set out seedlings	Short cold-damp	Moist	Summer	Subtle-taller
***Asclepias tuberosa Butterfly Weed	High!	Low	Set out seedlings	Short cold-damp	Mesic to Dry	Summer	Very showy
Asclepias viridiflora Short Green Milkweed	Very high!	Low	Set out seedlings	Short cold-damp	Mesic to Dry	Summer	Subtle-shorter
**Aster azureus Sky-blue Aster	High	Moderate	Forb planting or by seedlings	Cold-damp	Mesic to Dry	Fall	Showy
*Aster ericoides Many Flowered or Heath Aster	Medium	Good	Easy	Cold-damp	Mesic to Dry	Fall	Moderate
**Aster laevis Smooth Blue ASter	High	Moderate	Forb planting or by seedlings	Cold-damp	Mesic to Dry	Fall	Showy
*Aster novae-angliae New England Aster	Low	Very good	Easy	Cold-damp	Mesic to Moist	Early Fall	Showy
Aster sericeus Silky Aster	High	Moderate	Forb planting or by seedlings	Cold-damp	Dry; Hill and Sand Prairies	Fall	Medium
*Baptisia leucantha White False Indigo	Medium	Good	Medium	Scarify	Mesic	Early Summer	Showy
Baptisia leucophaea Cream False Indigo	Very high!	Moderate	Forb planting or by seedlings	Scarify	Mesic to Dry	Late Spring	Showy
Callirhoe triangulata Clustered Poppy Mallow	High	Moderate	Forb planting or by seedlings	Cold-damp	Dry, Sand Prairie	Summer	Very showy
**Camassia scilloides Wild Hyacinth	High	Moderate	Forb planting or by seedlings	Cold-damp	Mesic to Moist	Late Spring	Low showy
Castilleja coccinea Indian Paintbrush	High!	Parasitic	Difficult Sow seed densely in established prairie	Plant immediately	Mesic to Dry	Late Spring	Very showy

*Restoration easy in grass or mixed planting
**Moderate response in mixed planting; best in the forb planting
***Very competition sensitive; start seedlings, then set out

Prairie Forbs	Quality	Competitive Ability	Ease of Restoration	Seed Conditioning	Habitat	Flowering	Showiness
Ceanothus americanus New Jersey Tea	High!	Moderate	Best by seedlings	Boiling H_2O-2 min.	Mesic	Early Summer	Showy
***Cirsium hillii Hill's Thistle Problematical species; occurred perhaps in grazed prairies originally	High	Low	By seedlings short-lived; needs to re-seed inself	Cold-damp?	Mesic to Dry	Early Summer	Showy
Comandra richardsiana False Toadflax	Medium	Parasitic	By seedlings with other species	Cold-damp?	Mesic to Dry	Early Summer	Inconspicuous
**Coreopsis palmata Prairie Coreopsis	High	Good (May be allelopathic as clones develop)	Medium	Cold-damp	Mesic to Dry	Early Summer	Showy
*Coreopsis tripteris Tall Coreopsis	Low	Good	Easy	Cold-damp	Mesic	Summer	Tall but not showy
Delphinium virescens Prairie Larkspur (Note; Does not belong in Illinois prairies)	Medium	Moderate	Forb planting	Cold-damp	Mesic to Dry	Early Summer	Attractive
Desmodium canadense Showy Tick Trefoil	Medium	Aggressive (Do not plant too much)	Easy	Scarify	Mesic	Summer	Very showy
Desmodium illinoense Illinois Tick Trefoil	Medium	Good	Easy	Scarify	Mesic	Summer	Not showy
**Dodecatheon meadia Shooting Star	High	Moderate	Mixed, Forb planting or seedlings	Short, Cold-damp	Mesic to Dry	Spring	Very showy
*Echinacea pallida Pale Purple Coneflower	High	Excellent	Easy	Cold-damp	Mesic to Dry	Early Summer	Very showy
*Eryngium yuccifolium Rattlesnake Master	Medium	Excellent	Easy	Cold-damp	Mesic	Summer	Showy-unusual
Euphorbia corollata Flowering Spurge	Moderate	Good	Mixed or Forb planting	Cold-damp	Mesic	Summer	Moderate
Filipendula rubra Queen-of-the-Prairie	Very high	Moderate	Seedlings Cuttings (will grow in the garden prairie)	Cold-damp?	Specialized; Low, Wet, Calcareous	Summer	Tall; Very showy
**Gentiana andrewsii Bottle Gentian	High	Moderate	Forb or seedlings	Cold-damp	Moist	Fall	Showy
Gentiana flavida Yellow Gentian	High	Good	Easy in forb planting	Cold-damp	Mesic	Early Fall	Attractive

*Restoration easy in grass or mixed planting
**Moderate response in mixed planting; best in the forb planting
***Very competition sensitive; start seedlings, then set out

Prairie Forbs	Quality	Competitive Ability	Ease of Restoration	Seed Conditioning	Habitat	Flowering	Showiness
***Gentiana puberula Prairie Gentian	Very high!	Very low	Very difficult; Seedlings in established prairie	Cold-damp	Mesic	Fall	Low; Very showy
Geum triflorum Prairie Smoke	High	Moderate	Forb or seedlings	Cold-damp Plant soon	Mesic to Dry	Late Spring	Showy
***Habenaria leucophaea Prairie White Fringed Orchid	High	Low	Specialized; Difficult	Cold-damp?	Moist-Wet (Acid)	Mid-Summer	Low; Showy
*Helianthus rigidus Stiff Sunflower	Low	Aggressive (do not plant much)	Easy	Cold-damp	Mesic to Dry	Late Summer	Showy
*Helianthus occidentalis Western Sunflower	Medium	Aggressive	Easy	Cold-damp	Dry; Hill and Sand Prairie	Late Summer	Moderate
*Heliopsis helianthoides False Sunflower	Low	Good	Easy	Cold-damp	Mesic	Summer	Showy
*Heuchera richardsonii Alum Root	High	Medium	Mixed, Forb or seedlings	Cold-damp	Mesic	Late Spring	Subtle
***Hypoxis hirsuta Yellow Star Grass	Very high	Moderate	Forb or seedlings	Cold-damp	Mesic to Dry	Late Spring	Low-showy
***Krigia biflora False Dandelion	Very high	Low	Seedlings	Cold-damp	Mesic	Late Spring	Low-attractive
*Lespedeza capitata Round-headed Bush Clover	Low	Very good	Easy	Scarify	Mesic to Dry including Sand	Summer	Not showy, but adds interest
**Liatris aspera Rough or Button Blazing Star	Medium	Moderate	Mixed, but best in Forb planting	Cold-damp	Dry-Mesic, Hill and Sand	Late-Summer	Showy
**Liatris cylindracea Cylindrical Blazing Star	High	Moderate	Mixed, but best in Forb planting	Cold-damp	Hill Prairies, occasionally sand	Late-Summer	Showy
**Laitris pycnostachya Prairie Blazing Star	High	Moderate	Mixed, but best in Forb planting	Cold-damp	Mesic, Rich Soil	Mid-Summer	Very showy
***Lilium michiganene Turk's Cap Lily	High	Low	Seedlings, Special Handling	?	Moist Edge of Mesic Prairie	Mid-Summer	Very showy
***Lilium philadelphicum Prairie Lily (true prairie species)	Very high!	Low	Seedlings, Special Handling	?	Mesic Prairie	Mid-Summer	Very showy
***Lithospermum canescens Hoary Puccoon	Very high!	Low	Difficult: Needs Special Handling	Cold-damp Plant soon ?	Mesic	Spring	Very showy

*Restoration easy in grass or mixed planting
**Moderate response in mixed planting; best in the forb planting
***Very competition sensitive; start seedlings, then set out

Prairie Forbs	Quality	Competitive Ability	Ease of Restoration	Seed Conditioning	Habitat	Flowering	Showiness
***Lithospermum croceum Sand Puccoon	High	Low	Difficult; Needs Special Handling	Cold-damp ? Plant soon	Sand Prairies	Spring	Very showy
***Lithospermum incisum Fringed Puccoon	High	Low	Difficult; Needs Special Handling	Cold-damp and occasionally sand	Hill Prairies	Spring	Very showy
**Lobelia spicata Pale Spiked Lobelia	Medium	Moderate	Forb planting or seedlings	Cold-damp	Mesic to Dry	Late Spring Early Summer	Low profile, subtle
Oxalis violacea Violet Prairie Sorrel	Medium	Low	Bulbs and Runners; Seeds ?	Cold-damp ?	Mesic	Early Summer	Low-attractive
**Parthenium integrifolium Wild Quinine	High	Good	Mixed and Forb	Cold-damp	Mesic	Summer	Prominent, showy
Pedicularis canadensis Parasitic Wood Betony	Very high	Low	Parasitic; Easy from seed; plant with other species	Short cold-damp	Mesic	Late Spring Early Summer	Unusual, low-showy
**Petalostemum candidum White Prairie Clover	Very high	Medium	Mixed and Forb planting	Scarify	Mesic to Dry	Mid-Summer	Very showy
**Petalostemum purpureum Purple Prairie Clover	Very high	Medium	Mixed and Forb planting	Scarify	Mesic to Dry; Hill Prairies	Mid-Summer	Very showy
**Phlox pilosa Prairie Phlox	Very high!	Moderate	Forb planting and seedlings	Short Cold-damp	Mesic to Dry	Late Spring	Very showy
**Physostegia virginiana False Dragonhead	Very high	Moderate	Forb planting	Cold-damp	Mesic	Late Summer	Very showy
Polygala senega Seneca Snakeroot	High	Low	Forb planting or seedlings	Cold-damp	Mesic to Dry, Gravelly Prairies	Summer	Not showy
**Potentilla arguta Prairie Cinquefoil	High	Moderate	Forb planting	Cold-damp	Mesic to Dry	Mid-Summer	Tall; Interesting not showy
**Prenanthes aspera Rough White Lettuce	High	Medium	Mixed or Forb planting	Cold-damp	Mesic to Dry	Late Summer	Tall, not showy
**Prenanthes racemosa Smooth White Lettuce	Medium	Medium	Mixed or Forb planting	Cold-damp	Moist to Wet	Late Summer	Moderate
***Psoralea tenuiflora Scurfy Pea	High	Low	Forb or seed-lings; difficult	Scarify	Dry Hill Prairies	Early Summer	Delicate-showy
**Pycnanthemum virginianum Mountain Mint	Medium	Medium	Mixed or Forb planting	Cold-damp	Mesic	Mid-Summer	Showy
*Ratibida pinnata Yellow Coneflower	Low	Aggressive! (Do not plant too much!)	Easy	Cold-damp	Mesic	Mid-Summer	Showy

*Restoration easy in grass of mixed planting
**Moderate response in mixed planting; best in the forb planting
***Very competition sensitive; start seedlings, then set out

Prairie Forbs	Quality	Competitive Ability	Ease of Restoration	Seed Conditioning	Habitat	Flowering	Showiness
Rosa carolina Prairie Rose	Low	Medium	Mixed planting	Cold-damp	Mesic	Early Summer	Low-showy
*Rudbeckia hirta Black-eyed Susan	Low	Aggressive Go easy!	Easy	Cold-damp	Mesic to Dry	Summer	Showy
*Rudbeckia subtomentosa Sweet Black-eyed Susan	Medium	Aggressive	Easy	Cold-damp	Mesic	Summer	Showy
Ruellia humilis Hairy ruellia	Low	Moderate	Mixed or Forb planting	Cold-damp	Dry and Hill Prairies	Summer	Moderate
Salix humilis Prairie Willow	Medium	Moderate	?	?	Mesic to Moist	Spring	Not showy
*Silphium integrifolium Rosinweed	Low	Good	Easy	Cold-damp	Mesic	Mid-Summer	Moderately
*Silphium laciniatum Compass Plant	High	Excellent	Easy	Cold-damp	Mesic	Mid-Summer	Showy
*Silphium perfoliatum Cup Plant	Low	Good	Easy	Cold-damp	Low Moist	Mid-Summer	Moderately showy
*Silphium terebinthin-aceum Prairie Dock	High	Excellent	Easy	Cold-damp	Mesic to Dry	Mid-Summer	Showy
**Sisyrinchium albidum Blue-eyed Grass	High	Moderate	Forb or seedlings	Short Cold-damp	Mesic to Dry	Late Spring	Low-attractive
**Solidago riddellii Riddell's Goldenrod	High	Medium	Mixed and Forb	Cold-damp	Moist-Wet	Late Summer	Showy
*Solidago rigida Stiff Goldenrod	Medium	Good	Easy	Cold-damp	Mesic to Dry	Late Summer	Showy
*Solidago speciosa Showy Goldenrod	Medium	Good	Easy	Cold-damp	Mesic to Dry	Late Summer	Very showy
Spiranthes cernua Nodding Ladies Tresses	High	Low	Special Handling	Cold-damp?	Occasionally Moist to Wet Prairies	Late Summer	Low-showy
*Thalictrum dasycarpum Meadow Rue	Medium	Good	Mixed planting	Cold-damp	Mesic to Moist	Mid-Summer	Tall, moderately showy
**Tradescantia ohiensis Spiderwort	Low	Good	Mixed or Forb	Cold-damp	Mesic to Dry	Early Summer	Showy
**Veronicastrum virgin-icum Culver's Root	High	Low	Forb planting or seedlings	Cold-damp	Mesic	Mid-Summer	Very showy
**Viola pedata Birdsfoot Violet	Medium	Low	Forbs or seedlings	Short Cold-damp	Dry to Sandy	Late Spring	Low-showy

*Restoration easy in grass or mixed planting
**Moderate response in mixed planting; best in the forb planting
***Very competition sensitive; start seedlings, then set out

Prairie Forbs	Quality	Competitive Ability	Ease of Restoration	Seed Conditioning	Habitat	Flowering	Showiness
****Viola pedatifida*** Prairie Violet	Very high!	Low	Seedlings	Short cold-damp	Mesic	Late Spring	Low-showy
Zizia aptera Heart-leaved Meadow Parsnip	Very high!	Low	Forb planting or seedlings	Cold-damp	Mesic	Late Spring	Moderate
***Zizia aurea* Golden Alexanders	Medium	Good	Mixed planting	Cold-damp	Moist-Wet	Late Spring	Attractive

*Restoration easy in grass or mixed planting
**Moderate response in mixed planting; best in the forb planting
***Very competition-sensitive; start seedlings, then set out

LITERATURE CITED

Brakeman, W. G. 1975. Industry uses of prairie grasses for erosion control and landscaping, p. 417-418. In M. K. Wali (ed.) Prairie: a multiple view, Univ. N. Dakota Press, Grand Forks.

Rice, E. L. 1967. Chemical warfare between plants. Bios. 38:68-74.

Rock, H. W. 1974. Prairie Propagation Handbook. 3rd ed. Boerner Botanical Garden, Hales Corner, Wisc. 76 p.

Schramm, P. 1970. A practical restoration method for tall-grass prairie, p. 63-65. In P. Schramm (ed.) Proc. Symposium on Prairie and Prairie Restoration, Knox College, Galesburg, Ill.

Schramm, P. 1972. The Nisbet seed drill in prairie restoration, p. 151-152. In J. H. Zimmerman (ed.) Proc. Second Midwest Prairie Conf., Madison, Wis.

Schulenberg, R. 1970. Summary of Morton Arboretum prairie restoration work, 1963 to 1968, p. 45-46. In P. Schramm (ed.) Proc. Symposium on Prairie and Prairie Restoration, Knox College, Galesburg, Ill.

Schwarzmeier, J. 1973. What are our responsibilities in prairie restoration? p. 37-40. In L. C. Hulbert (ed.) Proc. Third Midwest Prairie Conf., Manhattan, Kan.

Threlfall, A. M. 1972. Studies on the germination of *Dodecatheon meadia*, p. 162-165.

Wilson, J. 1970. How to get a good stand of native prairie grass in Nebraska, p. 61-63. In P. Schramm (ed.) Proc. Symposium Prairie and Prairie Restoration, Knox College, Galesburg, Ill.

Wilson, R. E. 1970. The role of allelopathy in old-field succession on grassland areas of central Oklahoma, p. 24-25. In P. Schramm (ed.) Proc. Symposium on Prairie and Prairie Restoration, Knox College, Galesburg, Ill.

Zimmerman, J. H. 1972. Propagation of spring prairie plants, p. 153-161. In J. H. Zimmerman (ed.) Proc. Second Midwest Prairie Conf., Madison, Wis.

THE USE OF PRAIRIE IN STRIP MINE RECLAMATION

Peter Schramm and Richard L. Kalvin

Knox College
Galesburg, Illinois 61401

ABSTRACT

A mixture of prairie grasses and forbs was planted on a 0.4 ha (1 acre) strip mine site in Knox Co., west-central Illinois, in order to study the establishment and feasibility of prairie species in strip mine reclamation. Big bluestem (Andropogon gerardii) and Indian grass (Sorghastrum nutans) were mixed with thirteen species of forbs and planted with a Nisbet drill in late June 1976. The planting germinated after initial rains but suffered some loss of seedlings during an extended dry period. Moisture penetration and availability appears to be a decided limiting factor in the harsh, tight clay substrate left after strip mining. An earlier planting is recommended to utilize more abundant spring rainfall. The chemical and structural characteristics of the site are presented. Grasses were well established at the end of the first growing season and some of the forbs were evident.

INTRODUCTION

The problem of strip mining and the accompanying devastation of vegetation, soils and land forms is not a new one in this country. It is a process that has gone on for many years in various parts of the eastern and middle-western U.S. More recently, as the energy crisis and concerns over petroleum shortages have developed, strip mining has increased dramatically in many areas of the western U.S., particularly in the north-central Great Plains region. The process has continued in the East with renewed vigor as federal and state governments have called for less dependency on oil and a stepped-up use of coal as an alternative source of energy.

The concern for reclamation or lack of reclamation following the stripping process has long been voiced by many persons who had a concern for the basic productivity of the land itself. In some areas, such as Appalachia, the stripped areas are not only devastated mechanically, but are poisoned by the residues that remain after the mining process. In other areas, such as west-central Illinois, the substrate left after strip mining, although low in nutrient quality and devoid of structure and organic matter, will support vegetation of a successional nature. Such areas, if left alone, go through slowly progressing "old field" stages of succession including weedy annuals, biennial and perennial forbs, and a fast growing, softwood tree stage. Some of the trees, such as cottonwood (Populus deltoides), elm (Ulmus sp.), box elder (Acer negundo) and soft maple (Acer saccharinum), may come in rapidly, depending on the local seed sources, and form a mosaic of woody and herbaceous plant communities on the strip-mined land.

Public support, and even demand, for accelerated reclamation of strip-mined land has gradually increased in recent years, and on such land that will support vegetation, a search is currently underway for improved restoration techniques which will step up the return of the productivity of the land. Since much of the land currently being stripped is prime farmland consisting of black prairie soil that was generated for several thousand years by the rich flora of the tall grass prairie, it would seem logical to try prairie vegetation for reclamation purposes. The bulk of prairie flora consists of deep rooted perennials of both fibrous and tap-root types which hold soil very well, and will grow on a variety of sites. Many of the species originally occurred not only in deep black, loess soils, but also in harsher sites such as sand ridges, bluff tops, and limestone glades. Today, prairie species may be observed on low nutrient sites such as eroded road embankments, and on other waste sites where the absence of Eurasian weeds has allowed the establishment and persistence of prairie plants.

This study addressed itself to the establishment of several prairie grass species and a few selected forbs on a freshly strip-mined site in west-central Illinois. The site was planted in June 1976, establishment was followed and evaluated throughout that first growing season and the early part of the next growing season, prior to publication of this paper.

SITE LOCATION AND CHARACTERISTICS

The site chosen for a prairie planting was located 3.2 km (2 mi) north-west of Victoria, Knox County, Illinois, and had been strip mined the year before. It was part of the Mecco Mine property owned and operated by the Midland Electric Coal Company. The total area planted was approximately 0.4 ha (1 acre) within which was a more densely planted area of 0.13 ha (one-third acre). The site was scraped and leveled by bulldozer just prior to planting. Because of the extensive earth moving and depth of bulldozing involved in the leveling process, the newly exposed surface of the site was devoid of weed seeds which might germinate and compete with the prairie seedlings.

Table 1. Site soil characteristics

Sample	Soil pH	Kg per ha P	K	Ca	Mg	Acidity H_3O meg/100g	Percent Organic Matter	Sum of Cations meg/100g	Percent Cation Balance K	Ca	Mg	Percent sand	silt	clay	Soil Texture
Strip Mine 1	7.9	0.7	21	1215	180	0.0	0.7	20.77	0.68	79.68	19.64	26.0	49.2	24.8	loam
Strip Mine 2	8.0	0.7	22	1351	192	0.0	1.1	22.90	0.66	80.34	19.00	28.0	43.2	28.8	clay loam
Non-Stripped	7.3	2.6	33	984	156	0.0	2.8	17.13	1.34	78.23	20.43	17.0	61.2	22.8	silt loam

Table 2. Grass seedling densities per 0.5 m^2 and seedlings heights (end of growing season).

Plot ($p.5\ m^2$)	Number of Seedlings	Average Height of Seedlings (mm)
1 (dry)	3	40
2 (dry)	5	41
3 (dry)	6	44
4 (seepage)	12	73
5 (dry)	4	40

After the bulldozing process, the dense-planting area was fairly level, but the over-all site sloped slightly to the west. The larger rocks were removed by hand and final leveling was done by hand-raking in a few spots that needed such treatment.

The substrate that resulted was a rock strewn, clay-like surface which was really a conglomerate mix of many layers of over-burden that had been removed from above the coal seam and thoroughly mixed during the stripping and leveling process. Rocks included shales, limestone, sandstone, and igneous erratics from glacial till. Such a substrate is hard to define precisely, but structurally appears to be clay-like, cracking severely when dry (Fig. 1). Its water-holding capacity is low due in part to poor structure and lack of organic matter, and hence, water runoff is rapid and erosion on slopes may be severe in the absence of vegetative cover. The site's chemical and structural characteristics are defined in Table 1, which presents two randomly selected samples from the strip mine site and one sample from an immediately adjacent non-stripped site for comparison. Samples were analyzed by an agricultural testing laboratory.

Several points to note regarding these data from the strip mine site include the relatively high soil reaction (pH), low organic matter (normal amounts for humid prairie soils range from 3-5% and higher, Buckman and Brady 1969), very low phosphorus, and relatively low potassium. Calcium and magnesium, on the other hand, are present in more adequate amounts, and the cation-exchange capacity of the substrate is relatively good, probably due to the clay components present.

PLANTING PROCEDURES

The site was planted on 22 June 1976, using a Nisbet drill. 4.5 kg of big bluestem (Andropogon gerardii) were thoroughly mixed with 4.5 kg of Indian grass (Sorghastrum nutans) and 3.2 kg of forb seed. This total quantity was drilled into the site by two passes over the entire area and two additional passes (total of four passes) over the densely planted area, giving approximately 2.75 kg per ha seeding rate for the peripheral area, and over 5.5 kg per ha seeding rate for the densely planted area. The drill operated quite successfully in spite of the rock still present on the site, with no damage to the planting discs. The 3.2 kg of forb seed included Coreopsis palmata, Desmodium canadense, Echinacea pallida, Eryngium yuccifolium, Liatris aspera, L. pycnostachya, Parthenium integrifolium, Petalostemum candidum, P. purpureum, Potentilla arguta, Ratibida pinnata, Silphium laciniatum and S. terebinthinaceum.

Two days after planting 25 mm (1 inch) of rainfall was recorded on the site. Seven days later, a second rain of less than 12 mm (0.5 in) fell, and germination was evident ten days after the first rainfall. Then there followed a period of three-and-one-half weeks of no rain.

RESULTS AND DISCUSSION

There was good germination of both grasses and forbs after the initial rainfall. All seeds but the legumes were cold-damp conditioned up to the time of planting and were ready for prompt germination, which is an important factor in any prairie planting. A problem arose after the initial germination when an extended dry period set in. Under normal conditions, in most soil types, 25 mm-plus of rainfall would have been more than enough to not only germinate the seed, but penetrate several cm and ensure adequate subsurface moisture for root penetration and establishment of the prairie seedlings. In the tight, clay substrate of the strip mine site, moisture penetration was very poor and it became evident that the seedlings were in trouble and dying as the surface dried to an almost concrete-like hardness during the extended dry period. At this point a portable pump was used to irrigate the site from a nearby strip mine lake. With the moisture from a few days of pumping and some additional rainfall in August, many seedlings survived and good establishment was evident for both grasses and forbs (Figs. 1, 2).

It is indicated by the mid-summer drought problem and loss of seedlings that perhaps an earlier planting date would have been more successful. It has been noted that, for most prairie plantings, a late spring-early summer planting date is desirable to allow germination of weed seed, shallow cultivation, and elimination of potential weed competition prior to planting (Schramm 1970). It would appear, however, in fresh strip mine substrates where weed seed is not present, an early to mid-spring planting date is more desirable to take advantage of the greater rainfall that occurs at that time. Prairie seedling roots penetrate very rapidly and deeply during the first few weeks of growth, but they must have adequate moisture to achieve this growth. A spring planting would not only increase available moisture, but also extend the first growing season, and result in better survival and establishment.

At the end of the growing season, in early fall after the grass seedlings had turned color, five ½ m^2 plots were randomly selected in the denser planting area to determine grass densities and heights. These data are presented in Table 2. The samples are fairly comparable except for plot 4 which was located in a low spot where seepage of sub-surface moisture was evident for most of the summer. The 73 mm height, although less than growth usually achieved in more normal soil types in this part of the mid-west, is respectable considering the lower nutrient qualities of the site, indicated in Table 1. The grasses of plot 4, when compared to the other plots with no seepage, were approximately twice as high and twice as dense as grasses from the dryer plots. Even so, the average density of the dryer sites (4.5 plants/0.5 m^2) represents a respectable stand and, at maturity, the basal areas of these large species of prairie grass would more than adequately fill the areas they occupy. Clearly, soil moisture plays a key role in limiting or promoting the early growth and development of prairie grasses on these strip mine sites.

Survival and establishment of several species of forbs were evident over the entire planting site. Forb seedlings are always less evident and harder to locate the first season than grass seedlings, but certain species became obvious. The Silphium spp. were especially evident and did very well (Figs. 2,3). The long tap roots of compass plant (Silphium laciniatum) and prairie dock (S. terebinthinaceum), and the rapid growth and depth of penetration of these structures the first growing season, make these species admirably suited for strip mine sites. Figure 3 shows a compass plant early in the second growing season with a second year size and leaf form typical of normal soil sites. Other forbs that were definitely identified and well established on the site were prairie clovers (Petalostemum spp.), pale purple coneflower (Echinacea pallida), and showy tick trefoil (Desmodium canadense). As with most prairie plantings, forb establishment is best evaluated several years after the initial planting. It is expected that a number of species will become evident as the planting develops in the future.

It is concluded from this initial study of prairie in strip mine reclamation, that a number of prairie species will definitely grow on these harsh sites, that moisture more than nutrients may be a limiting factor in such a site, and that an earlier, spring planting may compensate for limiting moisture.

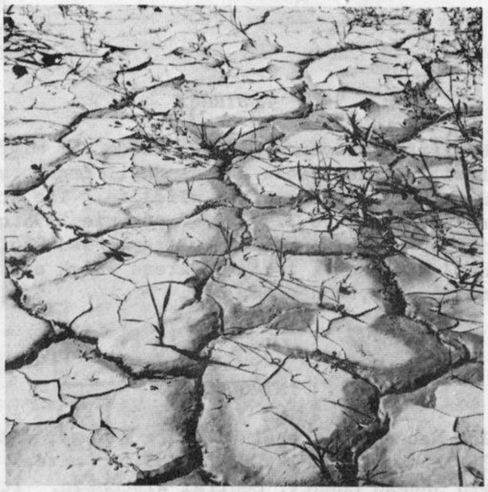


Fig. 1. Prairie grass seedlings established in the cracked and drying substrate of the strip mine planting site.

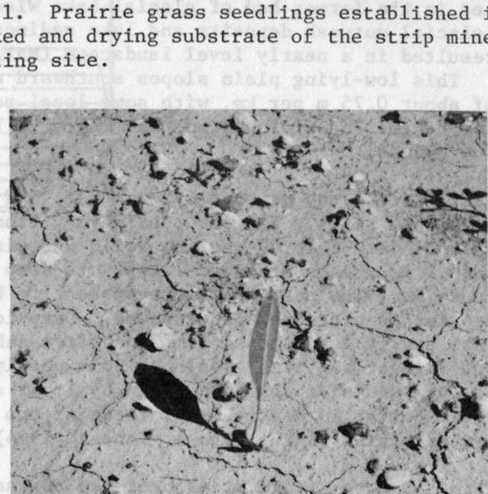


Fig. 2. Prairie dock seedling (Silphium terebinthinaceum) established on strip mine site, the first season.

ACKNOWLEDGMENTS

We wish to thank the Midland Electric Coal Company for the use of the site, for the leveling that was done, and for the use of their irrigation hose. This study was supported by a National Science Foundation Undergraduate Research Participation Grant No. SMI76-03213.

LITERATURE CITED

Buckman, H. O., and N. C. Brady. 1969. The nature and properties of soils. (7th ed.) Macmillan, London. 653 p.

Schramm, P. 1970. A practical restoration method for tall-grass prairie. In: P. Schramm (ed.), Proc. Symp. Prairie and Prairie Restoration, Knox College, Galesburg, Il. pp. 63-65.

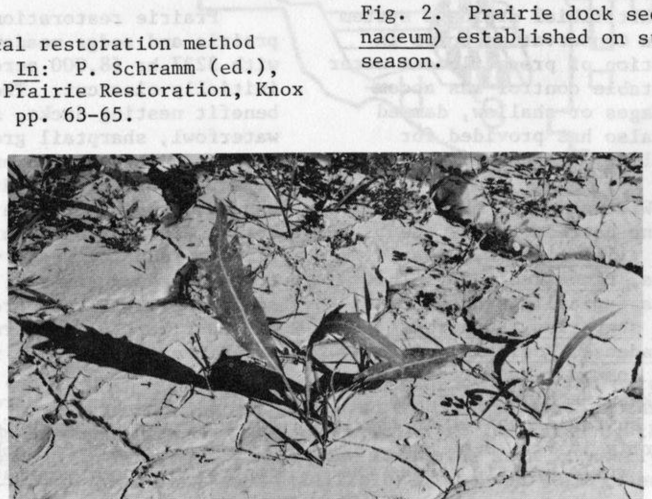


Fig. 3. Compass plant (Silphium laciniatum) on strip mine site early the second growing season.

PRAIRIE AND SAVANNA RESTORATION IN THE NECEDAH NATIONAL WILDLIFE REFUGE

Thomas Blewett
Department of Botany
University of Wisconsin
Madison, Wisconsin 53706

ABSTRACT

Habitat improvement is evaluated for migratory waterfowl, nesting ducks and sandhill cranes with secondary benefits for other wildlife. The scope of the project includes 3237 ha of prairie, 393 of wildlife openings, 101 of farm grass, and 275 of savanna. Management includes areas which are burned, selectively cut, and clear cut.

INTRODUCTION

The Necedah National Wildlife Refuge, established in 1939, consists of 16,003 ha (39,543 acres) in northern Juneau County, central Wisconsin. It is situated in the former bed of glacial Lake Wisconsin where glacial outwash deposits and lake sediments have resulted in a nearly level landscape (Martin 1965). This low-lying plain slopes southward at the rate of about 0.75 m per km, with some local relief provided by the underlying sandstone where it rises into low mounds.

Soils are of two general types, peat, and loamy fine sands and silts. The peat soils vary from depressional dark-colored shallow soils underlain by coarse soil materials or mineral soils to deep poorly-drained soils. The peat soils are subject to heavy wind erosion when drained and exposed. Deep loamy sands are nearly level to sloping and often subject to local drought and wind erosion. Some poorly drained loam and silt loam underlain by loose sands and gravels exist in nearly level areas of the southern one-third of the refuge (Karasch 1964).

With the water table at or near the surface, peat and wet sandy soils are common. Artificial drainage modified the subsoil water table when farming was attempted in the late 1800's and early 1900's; subsequently, dry sandy soils and unstable, drained peat soils forced abandonment of most farms in the area. Although the artificial drainage system was improved by the Civilian Conservation Corps in the 1930's, partial restoration of presettlement water table conditions and water table control was accomplished by a system of flowages or shallow, dammed lakes. The flowage system also has provided for greater flexibility in wildlife management.

Historically, central Wisconsin was characterized by scrub oak savanna and pine barrens, where the dominant trees were Quercus ellipsoidalis, Pinus banksiana and, in some areas, Pinus resinosa. The open-growth ground layer was typically sand barren vegetation where Andropogon scoparius, Euphorbia corollata, Helianthemum canadense, Koeleria cristata and Lespedeza capitata were common. Many reptiles, including the hog-nosed snake, the blue racer and the six-lined lizard, found suitable habitat in the sand barren environment (Curtis 1959). Deer and ruffed grouse were uncommon, while prairie grouse was abundant (Updike 1975).

RELATION OF PRESCRIBED BURNING TO REFUGE OBJECTIVES[1]

Prescribed burning began on a small scale in 1944 and was expanded to include 4047 ha (10,000 acres) after 1968. The principal objective is habitat improvement for nesting and migratory waterfowl as well as for prairie fowl. The benefits for sandhill cranes have already been realized as their peak fall numbers have increased from less than 100 fifteen years ago to over 400 in recent years, and resident cranes have increased in numbers. Waterfowl production appears to have increased in recent years, and sharptail grouse and prairie chicken can be reintroduced as their former habitat is reopened.

Additional benefits, incidental to prairie fowl and waterfowl objectives, include habitat improvement for insect, reptile and mammal inhabitants of sand prairies and savannas. Harvester ants have been a part of the prairie community where they build mounds 15 to 30 cm in height and 1 to 1.5 m in diameter within clearings of up to 9 m in diameter (Costello 1969). Ant mounds are common in the refuge and provide an opportunity for research in relation to different burn and nonburn management strategies. Reptile habitat is similar to the Spring Green Prairie, a Wisconsin Scientific Area, where eleven species of reptiles can be found. Similarly, changes in small mammal populations in response to different management strategies can be examined.

Savanna restoration is an important concept in Wisconsin, because oak and pine savannas formed a large part of presettlement vegetation. A portion of the savanna project has been designated as Wisconsin's first savanna Scientific Area and should benefit turkey reintroduction efforts.

PROGRAM UNITS AND TIMING OF BURNS

The Refuge currently manages a total of 4006 ha (9,900 acres) in 58 units through the use of fire. Primarily, four land use categories are included in the burning program: 1) prairie, 2) wildlife opening, 3) farm grass, and 4) savanna (Fig. 1).

Prairie restoration, including potential sand prairie and sedge meadow, is the largest category with 3237 ha (8,000 acres), much of which was initially clearcut. The prairie is intended to benefit nesting ducks, sandhill cranes, migratory waterfowl, sharptail grouse and prairie chicken. Burns are recommended once every three-to-five years with the objective of discouraging woody vegetation and encouraging prairie grasses and forbs. Summer burns, from August to mid-September, are most effective in reducing woody vegetation, but less beneficial to warm-season grasses, and potentially damaging to soil. Spring burns, from late March to late April, are most helpful to warm season grasses, and are sometimes necessary to reduce aspen and high brush. A spring fire, however, may be harmful to nesting wildlife and can be more explosive than summer burns. Early spring burns, before mid-March, and late fall burns, after mid-September, appear to provide little control of woody vegetation.

[1] The fire management objectives and discussion of program units and management problems are based upon a management plan by former Refuge Manager, Gerald Updike (1975).

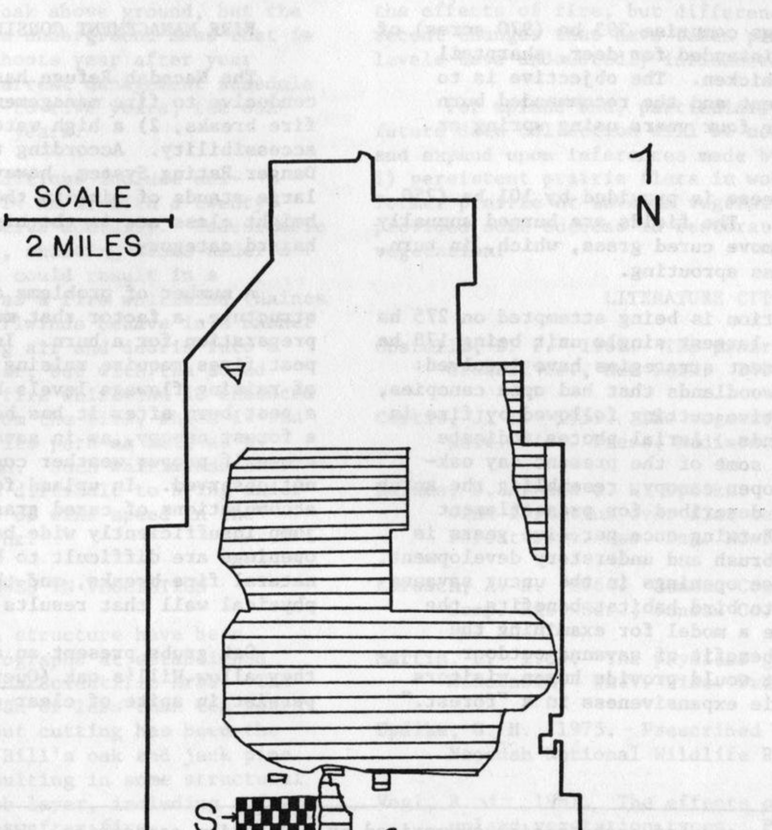


Fig. 1. Fire management area in the Necedah Refuge. The extent and area of burning management is indicated by the patterned areas within the Refuge boundary. Savanna restoration is indicated by the checkered patterns marked S while the remaining area is mostly prairie restoration with some wildlife openings and farm grass. The Refuge headquarters is indicated by H.

Wildlife openings comprise 393 ha (970 acres) of the program and are intended for deer, sharptail grouse and prairie chicken. The objective is to limit shrub development and the recommended burn frequency is once per four years using spring or summer burns.

Fall feed for geese is provided by 101 ha (250 acres) of farm grass. The fields are burned annually in late summer to remove cured grass, which, in turn, encourages grain grass sprouting.

Savanna restoration is being attempted on 275 ha (680 acres) with the largest single unit being 178 ha (440 acres). Management strategies have involved: 1) burning oak-pine woodlands that had open canopies, and 2) initial selective cutting followed by fire in closed canopy woodlands. Aerial photos indicate that as late as 1935 some of the present day oak-pine woodlands were open canopy, resembling the scrub oak savanna that was described for presettlement central Wisconsin. Burning once per five years is intended to control brush and understory development, as well as to increase openings in the uncut savanna units. In addition to bird habitat benefits, the savanna units provide a model for examining the potential aesthetic benefit of savanna outdoor recreation areas that would provide human visitors the feeling of prairie expansiveness in a "forest."

FIRE MANAGEMENT CONSIDERATIONS AND PROBLEMS

The Necedah Refuge has three characteristics conducive to fire management: 1) many physical fire breaks, 2) a high water table, and 3) off-road accessibility. According to the National Fire Danger Rating System, however, the scrub oak and large stands of pine in the three-to-six meter height class are in the highest potential fire hazard category.

A number of problems are related to vegetation structure, a factor that must be understood in preparation for a burn. In marshlands, potential peat fires require raising the water table by means of raising flowage levels before a burn, or flooding a peat burn after it has been detected. Fire under a forest canopy, as in savanna burns, could easily crown if proper weather conditions and control are not observed. In upland forest with no overstory, accumulations of cured grass could allow fire to jump insufficiently wide backfire breaks. Wildlife openings are difficult to burn because they lack natural fire breaks, and the forest edge forms a physical wall that results in unpredictable winds.

Oak grubs present an additional problem in that they allow Hill's oak (Quercus ellipsoidalis) to persist in spite of clear-cutting and periodic fires.

Table 1. Percent frequency of each species summarized by vegetation categories. Woods, savanna and prairie were sampled with 64 quadrats each, and the marsh categories were sampled with 56 quadrats each.

	Woods	Savanna	Prairie	Unburned marsh	Burned marsh
Andropogon gerardii	16	28	23	0	0
Andropogon scoparius	30	48	50	2	2
Carex pennsylvanica	95	92	95	11	36
Carex oligosperma	0	0	0	45	14
Danthonia spicata	2	5	19	2	2
Gaylussacia baccata	14	16	5	9	16
Helianthemum canadense	27	19	16	0	0
Koeleria cristata	2	16	20	0	0
Maianthemum canadense	33	16	5	0	2
Oryzopsis pungens	3	12	23	0	0
Polytrichum sp.	0	6	3	5	41
Quercus ellipsoidalis	61	44	20	7	4
Rubus sp.	19	14	25	36	63
Rumex acetosella	0	3	33	0	0
Sphagnum sp.	0	0	0	27	21
Spirea alba	0	2	0	9	14
Vaccinium angustifolium	34	20	13	14	32

Fire will eliminate Hill's oak above ground, but the root can survive, forming an underground mass that is capable of developing new shoots year after year (Curtis 1959). Under the current management schedule of burning once every three-to-five years, the oak grubs will persist for many years.

Preferred weather conditions include unidirectional winds of 12 to 24 km/hr with a twenty-five to fifty per cent relative humidity. Undesirable conditions exist with light, shifting winds under a high pressure system, which could result in a dangerous phenomenon known as a fire whirlwind (Haines and Updike 1971). Fire whirlwinds behave in a manner much like tornadoes, drawing air and debris into a spinning column of rising air, but with the added fire. The strength of the fire whirlwind is enhanced by the hot air resulting from the fire, which is fed by combustible material in its path as well as by debris drawn into the column. Such whirlwinds have occurred at Necedah and are difficult to bring under control, although estimates of wind speed in the funnel do not exceed 56 km/hr.

ANALYSIS OF CHANGES IN VEGETATION

Changes in vegetation structure have been documented by periodic photographs at established photo stations in the Savanna Scientific Area. The photographs cover a time span of less than ten years in an area where fire without cutting has been the management practice. Most Hill's oak and jack pine have survived the fire, resulting in some structural change apparent in the shrub layer, including a few patches of aspen development after fire.

Changes in vegetation composition have been examined on the basis of presence-absence data from circular 1 m^2 and 5 m^2 quadrats. The data were collected for two stands each of unburned woodland, savanna, prairie, unburned marshland, and burned marshland in the summer of 1975. Since this data set is the first that is available for examining compositional change, a time series analysis of compositional change is not possible and inferences about change must be made on the basis of differences between stands having different kinds of management.

Of the 150 species examined, the per cent frequencies of sixteen common species are summarized in Table 1. Upland species which have notably greater frequencies under fire management are Danthonia spicata, Koeleria cristata, Oryzopsis pungens and Rumex acetosella, while Maianthemum canadense is notably less common in open burned sites. Although the bluestems (Andropogon spp.) have a greater frequency in the burned sites, they remain quite frequent in wooded areas. The persistence of the bluestems under incompletely closed canopies probably reflects a short time span since the savanna was overgrown by trees. Vogl (1961) found that savanna or prairie that has been protected from fire for 25 to 60 years will survive because respiratory demands can be met so long as the canopy has not had time to sufficiently close and eliminate prairie flora.

Although Carex oligosperma is more common in unburned marshland and Spirea tomentosa is more common on burned sites, it is not clear that these and other compositional differences are a result of fire management. As in the upland comparisons, edaphically similar wetlands were sought to compare the effects of fire, but differences in drainage and recent changes that have taken place in water table levels have undoubtedly influenced composition.

For upland and, particularly, wetland vegetation, future data collection will be necessary to confirm and expand upon inferences made by the 1975 data that 1) persistent prairie flora in woodlands suggest former prairie or savanna vegetation, and 2) fire has provided some success in restoration of sand barren vegetation.

LITERATURE CITED

Costello, D. F. 1969. The prairie world. T. Y. Crowell Co., New York. 242 p.

Curtis, J. T. 1959. The vegetation of Wisconsin. Univ. Wisc. Press, Madison. 657 p.

Haines, D. A. and G. H. Updike. 1971. Fire whirlwind formation over flat terrain. U.S.D.A. Forest Serv. Res. Pap. NC-71. 12 p.

Karasch, A. J. 1964. Juneau County soils data. Coop. Ext. Ser., Juneau Co. Courthouse. 26 p.

Martin, L. 1965. The physical geography of Wisconsin. Univ. Wisc. Press, Madison. 608 p.

Updike, G. H. 1975. Prescribed burning plan - Necedah National Wildlife Refuge.

Vogl, R. J. 1961. The effects of fire on some upland vegetation types. Ph.D. Dissertation. Univ. of Wisc. 154 p.

THE PRAIRIE CORRIDOR CONCEPT: POSSIBILITIES FOR PLANNING LARGE-SCALE PRESERVATION AND RESTORATION

Donald M. Reed

Southeastern Wisconsin Regional Planning Commission
and
Department of Biology, University of Wisconsin - Whitewater

and

J. A. Schwarzmeier

Waukesha County Park and Planning Commission
Waukesha, Wisconsin

ABSTRACT

The prairie corridor is shown to be a type of environmental corridor that can easily be defined with the aid of widely available planning resources (soils maps, USGS maps, etc.). Application of this approach to Waukesha County and environs suggests three levels of prairie corridor intensity. The conclusion is that large-scale prairie preservation and restoration efforts are best planned within areas meeting the criteria of "primary" prairie corridor condition in stand size, quality, and concentration.

INTRODUCTION

This paper proposes to demonstrate that planning large-scale prairie preservation or restoration is effective if based on a corridor approach. Although developed for southeastern Wisconsin, where land use not compatible to natural areas is intensive, similar methods of corridor networks may prove helpful in other regions.

The prairie corridor concept applies Schwarzmeier's (1973) recommended approach to prairie restoration. Schwarzmeier expressed serious concern about the effect of large-scale or widespread seeding of non-native strains, particularly from commercial sources. That paper stated that a sounder approach would concentrate restoration efforts on managed expansions of remnants using native seed without environmental corridors. This paper will explore the idea that such an approach would also be more efficient than ordinary prairie seedings, especially if applied to prairie types of environmental corridors, where ambient prairie seed and soil conditions are already conducive to the spread of prairie vegetation.

Rationale. The rationale for preserving and restoring midwestern prairies generally does not include any obvious economic factors. However, the aesthetic, cultural, ecological, educational, and scientific values of these prairies are immense. Land managers and public officials who deal with land resources must examine these other values in the decision-making process even though the economic worth of these remaining prairies appears to be nonexistent or elusive. As Aldo Leopold (1966) wrote "...a system of conservation based solely on economic self-interest is hopelessly lopsided. It tends to ignore, and thus eventually to eliminate, many elements in the land community that lack commercial value, but that are--as far as we know--essential to its healthy functioning. It assumes, falsely, I think, that the economic parts of the biotic clock will function without the uneconomic parts".

To this non-economic end the prairie corridor concept is advanced herein as a "tool" with which the land manager and public official can quantitatively identify and delineate those prairie areas with the maximum potential for preservation and successful restoration.

The Environmental Corridor Concept. Early planning approaches which used an environmental corridor as an efficient method of preserving natural features have been credited to C. B. Whitnall of the Milwaukee County Park Commission in 1906 (Katz and Sollen 1976). More recently, Lewis (1964) has employed the method in mapping Wisconsin's land resources. The high concentrations of features on Lewis' maps generally involved riverine wetland corridor systems. The Southeastern Wisconsin Regional Planning Commission (SEWRPC 1966) adopted the environmental corridor concept as a basic planning tool in developing its comprehensive regional land-use plan for southeastern Wisconsin. The SEWRPC plan has defined the environmental corridor as an essentially continuous, linear pattern on the landscape consisting of a composite of natural resources and related elements important to maintaining the overall environmental quality of southeastern Wisconsin (Walesh 1976). Elements incorporated in the SEWRPC system include: 1) surface waters and their associated floodplains; 2) woodlands; 3) wetlands; 4) wildlife habitats; 5) wet or poorly drained soils; 6) areas of rough terrain and high local topographic relief; and 7) significant geological formations and physiographic features. The system, however, has yet to specifically incorporate prairie communities.

Description of the Study Area. The study area lies along the western edge of the rapidly expanding Milwaukee metropolitan area (Fig. 1). It includes the entire 1492 km^2 (576 mi^2) of Waukesha County and an adjacent 207 km^2 (80 mi^2) in Walworth and Jefferson Counties. The eastern portion of the study area, and satellite developments near major highway routes and such municipalities as Oconomowoc, Waukesha, and Whitewater, are suburban. However, the study area exhibits a generally rural land use on approximately 1300 k^2 (502 mi^2) or 76 percent of its area (SEWRPC 1976).

The continental climate is characterized by wide ranges in annual temperature and precipitation. Specifically, the study area receives an average precipitation 76.5 cm (30.1 in.) annually, of which 60 to 66 percent falls during the 160 day growing season (SEWRPC 1976, Wisconsin Department of Transportation 1976). The temperature ranges from an average daily mean of 22.3° C (72.1° F) in July to an average daily mean of -6.3° C (20.7° F) in January (SEWRPC 1976).

An interlobate moraine varying from 1.6 km

(1 mile) to 4.8 km (3 miles) in width extends north to south through the western portion of the study area. The remainder of the area is undulating ground moraine, except for an outwash plain which extends 1.6 km (1 mile) to 4.8 km (3 miles) beyond the interlobate moraine. Predominant soils of the interlobate moraine system belong to the sandy Rodman-Casco complex. Most prevalent in the outwash plains are Fox and Warsaw loams, while Hocheim and Theresa silt loams are associated with the ground moraine. Finally, the wetland soils scattered throughout the study area belong to the Adrian, Houghton, and Palms muck complexes.

Prairie Vegetation, Then and Now. The public land survey of 1836 classified about 30 percent of what is now Waukesha County as prairie and oak opening (Johnson and Schwarzmeier 1975). Less than 0.5 percent of that original prairie and oak opening remains today, and it occupies only 0.1 percent of the county's area.

Although fens were, and still are, a relatively common part of the study area's landscape, they have been omitted from this study except for those few which show a very strong prairie element. A total of 109 prairie stands encompassing 101 hectares (249 acres) have been identified within the study area. Many of these stands were no doubt contiguous in the past. At least 235 native vascular prairie species still exist in these stands (Wilson 1977).

METHODS

The prairie stands in this analysis were located by examining the files of the Waukesha County Park and Planning Commission, the Southeastern Wisconsin Regional Planning Commission, and the Wisconsin Department of Natural Resources' Scientific Area Preservation Council. Additional prairie stands were found through a poll of naturalists familiar with the study area. Areas likely to have additional prairies were identified by examining recent 1:4800 scale aerial photographs, USGS topographic maps, and Soil Conservation Service soils maps. New sites were field checked and all sites were classified by size, quality, and community type. A total of 109 prairie stands was recorded and analyzed in this manner.

For planning purposes, each stand was classed in one of the following five size categories: 1) 0.04 to 0.36 ha (0.1 - 0.9 acres); 2) 0.40 to 1.98 ha (1.0 - 4.9 acres); 3) 2.02 to 4.00 ha (5.0 - 9.9 acres); 4) 4.05 to 8.06 ha (10.0 - 19.9 acres); and 5) 8.10 ha (20.0 acres) or more. A quality rating of high or medium was assigned to each stand. High value stands included those prairies exhibiting a rich diversity and high integrity of native prairie plants and showing either little or no disturbance by man (such as grazing and plowing) or sufficient recovery from such disturbance. Medium quality stands were those containing a good diversity and integrity of native prairie plants and showing moderate to slight degrees of disturbance by man's activities. All "low" value stands were omitted because of the difficulty in locating even a small fraction of them; brush and weedy growth normally obscure these stands in any prolonged absence of fire.

The principle community type in each prairie stand was also recorded as wet, mesic, or dry. This system of three moisture levels was used instead of Curtis' (1959) five level system for two reasons: 1) individual stands were often composed of large proportions of two or more conventional prairie communities, and 2) plant "indicators" were often inconsistent with surface soil and catenal indicator relationships, especially for stands in lowland areas. A separate and full study to clarify all these indicative relationships appears to be needed in this region.

The prairie stands were assigned symbols of size,

TABLE 1

Characteristics of prairie stands by corridor within the study area.

Corridor	Area of Corridor km^2 (mi^2)	Prairie Stands: Number	Total Area ha (acres)	Mean Size ha (acres)	Mean Distance Between Boundaries meters (feet)[a]
Primary	83 (32)	54	79 (195)	1.5 (3.6)	1,116 (3,663)
Secondary	119 (46)	44	19 (48)	0.4 (1.1)	1,571 (5,155)
Tertiary	192 (74)	7	1.3 (3.3)	0.2 (0.5)	5,189 (17,024)
Non Corridor	1,300 (504)	4	1.1 (2.7)	0.3 (0.7)	18,012 (59,096)
Totals	1,700 (656)	109	100 (249)	0.9 (2.3)	3,852[b] (12,638)

[a] Calculations of interstand distances provided a theoretical basis for comparing spatial relationships among corridor designations. The average stand shape was assumed to be circular for purposes of calculation.

[b] Mean for the entire study area.

TABLE 2

Efficiency of initiating prairie restorations.

	Man-hours per hectare (acre)[1]
Burn release of prairie-old-field in environments favorable to prairie	6 (2.5)
Nisbet drilling of forbs and grasses (one pass each; Schramm 1972)	11 (4.5)
Manual broadcasting followed by dragging	36 (14.5)
Transplanting non-seeding plugs	210 (84.0)

[1] Figures include average times needed for final fire break or final seed/root bed preparation and for distributing and working in seed/plugs. Figures recorded by the Waukesha County Parks Naturalist staff during several small scale prairie restorations.

[2] "Prairie-old-field" as used in this study refers to areas where prairie species are common but dominant vegetation is ruderal prairie or alien plant species.

quality, and community type and then were mapped (Fig. 2). Using this stand map and a map of prairie soils, spatial relationships were noted and a corridor delineated to include existing or potential prairie sites. The corridor was subdivided into primary, secondary, and tertiary prairie corridors indicated as solid, cross-hatched and unhatched areas, respectively, in Fig. 3. The criteria used to separate the three corridor subsectors were density or number of stands per square kilometer, frequency of high quality prairies, and frequency of the larger prairies. The primary corridor was that area exhibiting the highest density and frequencies. The secondary corridor was that area exhibiting intermediate density and frequencies. Finally, the tertiary corridor was that area adjacent the two other corridor designations but showing lower density and frequencies. Each of the corridors was measured using a planimeter to determine its area.

Table 1 summarizes geographic features of the prairie stands within each of the three corridors as well as those located outside all corridors. The 83 km^2 (32 mi^2) of primary corridor contained 50 percent of the 109 prairie stands; the 119 km^2 (46 mi^2) of secondary corridor contained 41 percent of the prairie stands; the 192 km^2 (74 mi^2) of tertiary corridor contained only 6 percent of the stands. The remaining 3 percent of the stands were located outside the corridors.

Total prairie acreage, mean stand size, and mean interstand distance within each corridor are also shown in Table 1.

DISCUSSION

It became evident early in the study that both the concentration and average size of stands of prairie corridor quality continued beyond Waukesha County to the southwest. Therefore the study area was extended into adjacent Walworth and Jefferson Counties until stands meeting criteria for any of the three corridor designations ceased to occur.

The prairie corridors, as drawn, show a strong relationship to the irregular topography of the interlobate moraine, a large wetland area on the moraine's west, and an outwash plain containing Warsaw loam soils to the moraine's east. The secondary corridor takes the form of narrow belts, generally coinciding with railroad right-of-ways intersecting the interlobate moraine. The tertiary corridor occupies outwash plains composed of droughty soils which have been intensively farmed, but which abut one or both of the other corridors. Regardless of corridor location, however, two conditions persist for the primary and secondary corridor designations: first, a landscape condition which makes intensive use, particularly for agriculture, difficult; and second, and probably more important, an original prairie type vegetation according to the 1836 land survey (Johnson and Schwarzmeier 1975).

Within a planning context, then, the following definitions are proposed:

A <u>prairie corridor</u> is an area where large-scale prairie preservations and restorations can be performed without unduly taxing conventional tilling and wildland management facilities. Preservation or restoration requires successional processes and landscape features favorable to natural prairie takeovers of abandoned open lands within the corridor.

A <u>primary prairie corridor</u> is a landscape concentration of prairie-related features wherein a spread of prairie plant communities can be expected to occur, within short-term prairie successional time, to whatever portions are persistently managed by currently accepted practices favorable to prairie. A primary prairie corridor in a functional sense is an area where this has actually happened: where most stands are inter-connected by wide-ranging prairie relationships or by continuous prairie vegetation. The chief relationship of present concern are the movements of seed and vertebrates among prairie stands, especially because of gene flow and burrowings which give important sod-gap successional effects (see Curtis 1959, p. 292).

<u>Short-term prairie succession</u>, as used above, is a turnover in plant composition to a stage of prairie dominance within 1 to 25 years. This

TABLE 3

Regular travel range of mammals observed within the prairie corridor

Mammals	Regular travel range Diameter in meters (ft)
Opossum	400[a] (1,320)
White-tailed Jackrabbit	1,273[b] (4,200)
Mearn's Cottontail Rabbit	400[a] (1,320)
Wood Chuck	152[b] (500)
Franklins Ground Squirrel	106[b] (350)
Fox Squirrel	2,404[b] (7,920)
Red Fox	3,200[b] (10,560)
Raccoon	6,400[b] (21,120)
Mink	800[a] (2,640)
Badger	667[c] (2,200)
Striped Skunk	1,600[b] (5,280)
White-tailed Deer	3,200[d] (10,560)
Mean Travel Range	1,717 (5,666)

[a]Observations in Waukesha County made by the Retzer Nature Center staff.

[b]Jackson (1961).

[c]Sargeant and Warner (1972).

[d]Wisconsin Department of Natural Resources.

definition is based upon past experience and experiments in Wisconsin. The Crex Meadow Wildlife Area in Burnett County, Wisconsin (Fig. 1) showed a dramatic turnover in dominance from young forest to prairie in one to two years after the start of controlled burning (Curtis 1959). The shift in plant dominance involved some 70 long-suppressed, unnoticeable prairie species; this type of turnover will hereafter be referred to as the "Crex Meadow effect". In addition, a turnover in dominance from old-field to prairie plant species in a two year period has been demonstrated in Wisconsin prairie restoration plantings (Schramm 1972, Zimmerman and Schwarzmeier 1977). Thomson (1940) described abandoned fields on Wisconsin's "Central Sands" converting to prairie dominance in approximately 10 years without any management (this is a region of extensive original prairie vegetation).

Intensive prairie restoration on old fields in the University of Wisconsin-Madison Arboretum has resulted in "fair to good" stands within 14 years on sandy soils but only "poor to fair" stands in 24 years on heavy, deep silt loams (Curtis 1959). Extensive areas with the latter soils would ordinarily not qualify for prairie corridor status under previous definitions. Finally, it should be noted that 20 to 25 years is a reasonable and frequently used lead time in regional land use planning.

One of the most pertinent requisites of this paper's proposal is management practices that are fairly efficient when applied on a large scale. Table 2 indicates that the most natural method regarding propagule sources, burning, is also the most efficient to apply. In addition, wherever seed for natural dispersal is scarce, drilling or broadcasting are both relatively efficient when compared to transplanting.

Two tests of the concept's application. It is fortunate that large parts of the Scuppernong Marsh Wildlife Area within the primary corridor have burned since 1968. To our knowledge seven stands within the Scuppernong Marsh, totaling less than 10 ha, were known to area biologists before 1968. Now, after at least two large wild fires (over 2.5 km^2 each in 1968 and 1975), one small wild fire and at least two small controlled burns, some 19 prairie stands totaling 36 ha (89 acres) are known within the 5.7 km^2 (2.2 mi^2) area. Some of the "additional" prairie acreage no doubt represents smaller, less conspicuous stands overlooked before 1968. The majority of prairie, however, resulted from the fire-induced "Crex Meadow effect". Figure 4 shows the boundary of a 2.5 ha prairie within 250 m. of the Scuppernong Prairie State Scientific Area, a 5.0 ha prairie. The figured prairie was almost totally suppressed until the spring following an October 1975 wildfire. The fire line ended precisely at the sharp cutoff of big bluestem grass (*Andropogon gerardii*) floral stalks in the center of the photograph.

The Scuppernong Marsh section of the primary corridor, with its high concentration of 19 stands, appears to be a good example of a prairie corridor in a functional context. The 393 m (1297 ft) average interstand distance here should allow a functional interconnection of the stands in "short-term" time if proper management is applied. This proximity of stands indicates that a functional interconnection should already exist for many mammals which are known to exist in this area and which have regular travel range diameters greater than 400 m (Table 3). Not only is the average home range diameter of mammals in Table 3 more than four times the 393 m interstand distance, but according to Bielefeldt (pers. comm.) many birds of the area may disperse seeds over regular foraging ranges greater than 400 m. Such birds include, for example, ring-necked pheasants (*Phasianus colchicus*), sandhill cranes (*Grus canadensis*), mallards (*Anas plahyrhynchos*), mourning doves (*Fenaida macroura*), American crows (*Corvus brachyrhynchos*), and, via animal remains, great-horned owls (*Bubo virginianus*) and red-tailed hawks (*Buteo jamaicensis*).

Actually, two of the seven stands originally known, and several others of the 12 new stands located in the Scuppernong Marsh, were interconnected by continuous

TABLE 4

Prairie continuity in a railroad right-of-way survey, Waukesha County, 1976. Adapted from Manley 1976.

Railroad Right-of-way	Prairie Corridor	km (mi) surveyed	Percent of prairie cover on at least one side of the rails
Menomonee Falls to Merton	Non-Corridor	8.3 (5.2)	20
Waukesha to Genesee Depot	Secondary	7.5 (4.7)	56
North Prairie to Eagle	Primary	7.9 (4.9)	65

prairie vegetation by 1976. Thus, this Scuppernong portion of the primary corridor does demonstrate that most of the 19 stands are interconnected in at least one of the two ways attributed to a <u>functional</u> primary prairie corridor.

Another test of the prairie corridor concept uses a separate study (Manley 1976) of the percent of prairie cover within the right-of-ways of three railroads in the study area. Manley's data allow an examination of successional tendencies within corridor and non-corridor areas. The potential for circularity of reasoning is small because most of the railroad prairies (mapped by walking the 24 km (15 mi) of right-of-way) were too small or degraded to be used as stands for corridor delineations. Also, many of the better railroad stands were already known and mapped before Manley's study.

The percentage of "prairie old-field" or prairie was taken as a measure of the degree of prairie habitat continuity in the very narrow railroad right-of-way segments. This interpretation was possible because the percentages recorded on Manley's detailed maps could be examined and weighted for the length of rail segment they applied to. Table 4 summarizes the results of this analysis. When Tables 1 and 4 are compared there is a similar trend in the two measures of continuity--percent of prairie vegetation (Table 4) and average interstand distance (Table 1). The primary corridor's stands are more nearly continuous than those of the secondary corridor, and the secondary corridor's stands are more nearly continuous than those of the non-corridor areas. Of course there are difficulties with the comparison in a rigourous sense. Nevertheless, it does give evidence for expecting a more rapid successional spread of prairie plants within prairie corridors.

<u>Application of prairie corridor concept</u>. The size and spatial relationships necessary for planning natural reserves are currently matters of much biological research and interest. Discussions of these topics, however, illustrate a serious shortage of ecological fieldwork and subsequent planning which aim at the maximum natural functioning in whatever land use patterns are being adopted. The controversy over practical application is exemplified by recent articles on "island biogeography" theory (Sullivan and Schaffer 1975, Simberloff and Abele 1976, Diamond 1976). It should be noted that Simberloff and Abele (1976) propose that a corridor system connecting smaller reserve sites might represent a suitable compromise between opposing opinions.

Wilson (1977) has documented the high vulnerability to disturbance of the isolated prairie remnant in a suburbanizing and agricultural region. Emphasis on conservation programs for clustered prairie remnants in areas favoring prairie successional processes would thus seem more pracitcal than programs working on a single stand basis. Likewise, it seems more efficient to maintain certain prairie relationships, those depending on larger vertebrates for seed dispersal, for example, by emphasizing the preservation of prairies associated with other types of environmental corridors rather than prairies within some totally separate reserve system. The former method would simply involve adding prairie remnants as an eighth element in the environmental corridor delineation procedure now used by SEWRPC in southeastern Wisconsin.

The interstand distance of 393 m (1,290 ft.) within one set of existing prairies was earlier suggested as a possible level of primary corridor condition in a functional sense because of daily inter-connective wanderings by animals. Lesser degrees of inter-connection can also be practical (see Table 1). The values of 1,116 m (3,663 ft.) and 1,571 m (5,155 ft.) between stands should provide satisfactory seasonal interconnection on the primary and secondary levels. Also, some degree of daily inter-connective wanderings may occur since the regular travel ranges of some mammals listed in Table 3 are larger than the average interstand distances in both the primary and secondary corridors. The 5,189 m (17,024 ft.) between stands may allow some annual interconnection in the tertiary corridor areas. However, potential seed dispersal is reduced by a much smaller average stand area in these tertiary stands (MacArthur and Wilson 1967).

SUMMARY

Potential applications of the prairie corridor in preservation and land use planning are summarized as follows:

1. Expanding present environmental corridor delineations by adding another significant landscape element;

2. Providing a mapped base from which a functionally manageable type of prairie corridor can be set aside (often including a fire containment zone as well);

3. Providing a more efficient priority process in acquisition planning efforts;
4. Enacting appropriate zoning to restrict development within primary prairie corridors;
5. Requiring environmental impact statements on state and federally financed projects; at least within the primary prairie corridors, to address a project's efforts on the total corridor system;
6. Amending local burning ordinances to allow prairie management within at least the primary and secondary corridors;
7. Amending state and federal air quality standards to accommodate prairie burn management;
8. Refining buffer zones so that needed portions of adjoining prairie corridors are utilized in order of their grade;
9. Defining areas where efforts to locate presently unknown prairie remnants can be successfully realized; and
10. Facilitating large-scale prairie landscape restoration and preservation by:
    a. concentrating efforts in areas of micro-climatic and soil conditions favoring prairie plant growth;
    b. Providing a base for planning large-scale prairie animal studies or re-introductions;
    c. allowing potential seed dispersal and gene flow among naturally vigorous prairie strains;
    d. locating old-field areas with high potential for prairie restoration, partly because of readily available natural seed; and
    e. promoting reasonably rapid increases in prairie dominance through interaction of the four proceding principles and the "Crex Meadow effect".

Areas for future investigation concerning corridor refinement include:

1. Determining suitable minimum widths for prairie cover in railroad corridors which pass through residential/agricultural districts, and, thus, preserving uninterrupted travel lanes for seed-dispersing animals.
2. Focusing the need for research on, or related to many of the postulates of this paper. For example:
    a. data on the average distance of dispersal for each prairie plant species by its major dispersal agents;
    b. data on the average travel distances of vertebrates that are using the narrow prairie corridors which pass through non-prairie habitats;
    c. additional data on the effect of vertebrate digestive processes on prairie seed viability;
    d. data concerning potential corridor effects on the movements of prairie invertebrates.

The authors feel that the product of a corridor approach to prairie restoration and preservation, particularly in the primary prairie corridor, will not only be more ecologically desirable than large-scale commercial seed plantings, but will also be more easily and more economically achieved in the long run.

ACKNOWLEDGEMENTS

The authors are indebted to Mr. Ronald Kurowski, Wisconsin Department of Natural Resources Naturalist for the Southern Unit of the Kettle Moraine State Forest, Dr. S. Galen Smith of the University of Wisconsin - Whitewater, Mr. John Bielefeldt, and Mr. Trelen Wilson for locations and detailed descriptions of prairie stands in the study area. Also, Mr. James Riemer, Assistant Naturalist for the Waukesha County Park and Planning Commission, for locating and photographing stands in a 1975 wildfire area. Ms. Lynn Preston and Ms. Laurel M. Bagby assisted with the soils analysis. Finally the authors wish to thank the staff of the Southeastern Wisconsin Regional Planning Commission and Mr. John Bielefeldt for their most helpful review and comment.

LITERATURE CITED

Curtis, J. T. 1959. The vegetation of Wisconsin. Univ. Wisc. Press, Madison. 657 p.

Diamond, J. M. 1976. Island biogeography and conservation; Strategy and limitations. Science 193:1027-1029.

Jackson, Hartley H. T. 1961. Mammals of Wisconsin. Univ. Wisc. Press, Madison, Wisconsin. 504 p.

Johnson, M., and J. Schwarzmeier. 1975. Presettlement vegetation of Waukesha county 1836. 1 map.

Katz, J. M., and J. Sollen. 1976. A backward glance--Environmental corridors of yesterday and today. SEWRPC Tech. Record. 3(6):65-79.

Leopold, A. 1966. A sand county almanac. Oxford Univ. Press, N.Y. 269 p.

Lewis, P. 1964. Landscape resource inventory. Wisc. Dept. Resource Devel., Madison. 9 maps.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography. Princeton Univ. Press, Princeton, N.J. 203 p.

Manley, S. 1976. Impact on wildlife and vegetation of abandoning eighteen rail branch lines in Wisconsin. Tech. Report, Wisc. Dept. Transportation. Madison, Wisconsin. 37 p.

Sargeant, A. B., and D. W. Warner. 1972. Movement and denning habits of a badger. J. Mammal 23:380-391.

Schramm, P. 1972. The Nisbet seed drill in prairie restoration. In: Zimmerman, J. H. ed. Proc. Second Midwest Prairie Conference, Madison, Wisconsin. 151-152.

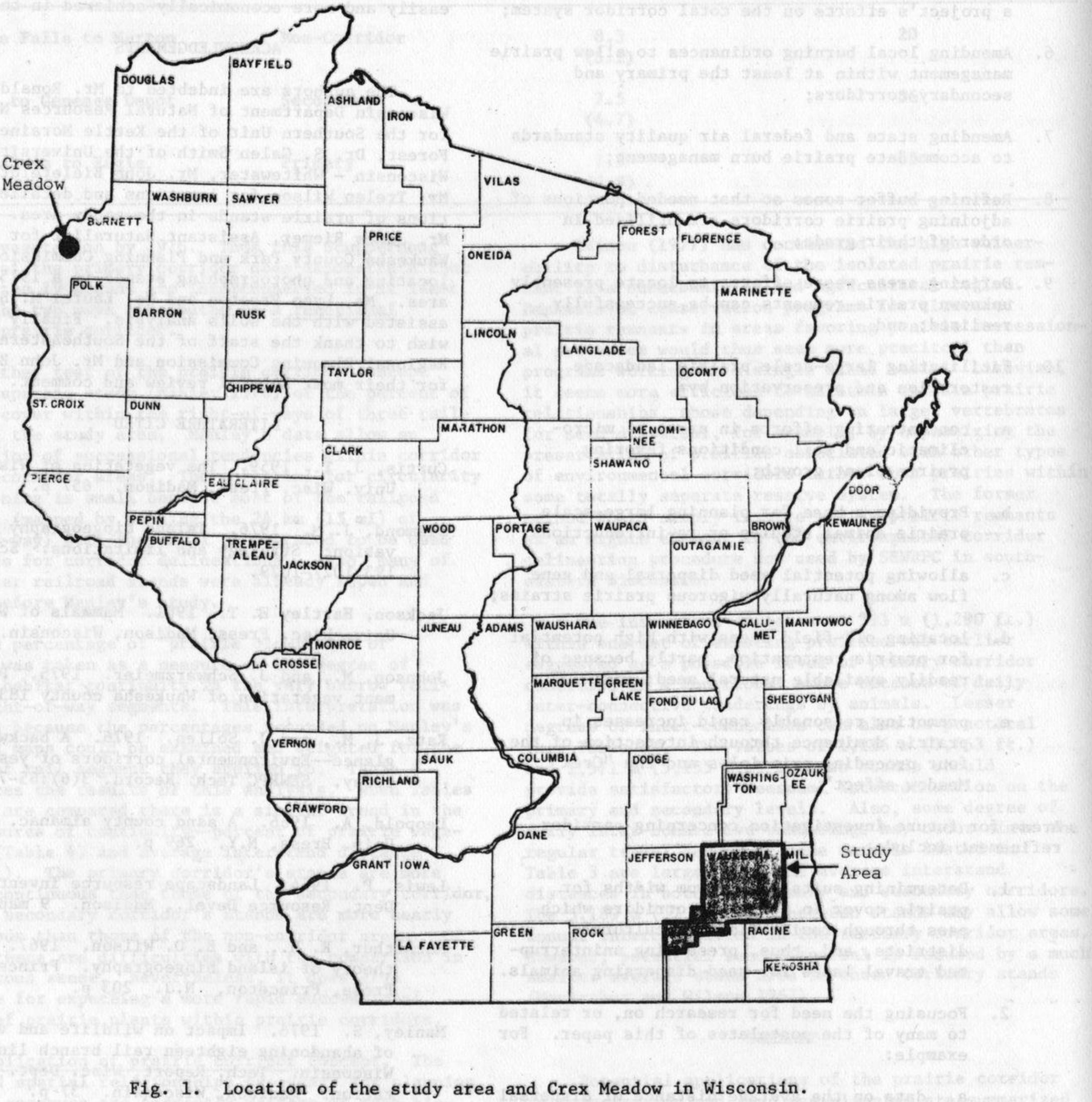


Fig. 1. Location of the study area and Crex Meadow in Wisconsin.

Schwarzmeier, J. 1973. What are our responsibilities in prairie restoration? In: L. Hulbert, ed. Third Midwest Prairie Conference Proc. Kan. State Univ. Biol. Div., Manhattan. pp. 37-40.

Simberloff, D., and L. C. Abele. 1976. Island biogeography theory and practice. Science. 191:285-86.

Southeastern Wisconsin Regional Planning Commission (SEWRPC). 1966. Planning Report No. 7, The land use - Transportation study, Forecasts and alternative plans - 1990. Vol. 2. Waukesha, Wisconsin.

Southeastern Wisconsin Regional Planning Commission (SWERPC). 1976. Planning Report No. 25. A regional land use plan and a regional transportation plan for southeastern Wisconsin -- 2000, Inventory Findings. Vol. 1. Waukesha, Wisconsin.

Sullivan, A. L., and M. L. Shaffer. 1975. Biogeography of the megazoo. Science 189:13-15.

Thomson, J. W. 1940. Relic prairie areas in central Wisconsin. Ecol. Monogr. 10:685-717.

Walesh, S. G. 1976. Floodland management: The environmental corridor concept. SEWRPC Tech. Record. 3(6):1-13.

Wilson, Trelen. 1977. A survey of some prairie remnants in Waukesha County, Wisconsin. These Proceedings.

Wisconsin Department of Transportation. 1976. Final environmental statements for STH 59 Whitewater to Waukesha. 451 p.

Zimmerman, J. H., and J. Schwarzmeier. 1977. Experimental prairie restoration at Wingra overlook. These Proceedings.

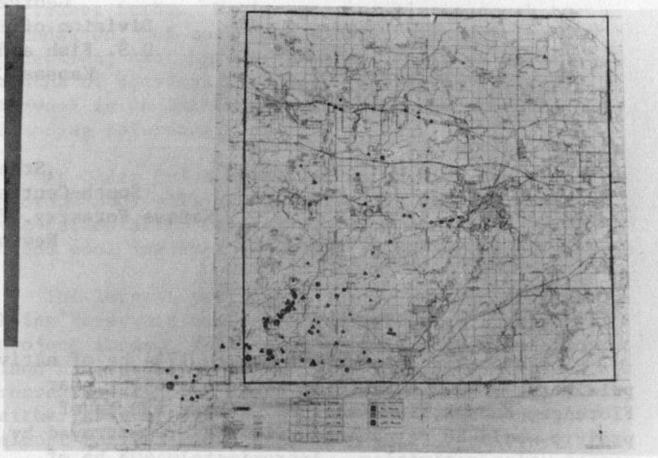


Fig. 2. Stands map. Triangle symbols denote medium quality stands and circles, the high quality stands. The relative sizes of these symbols correspond to the five size categories described in the text.

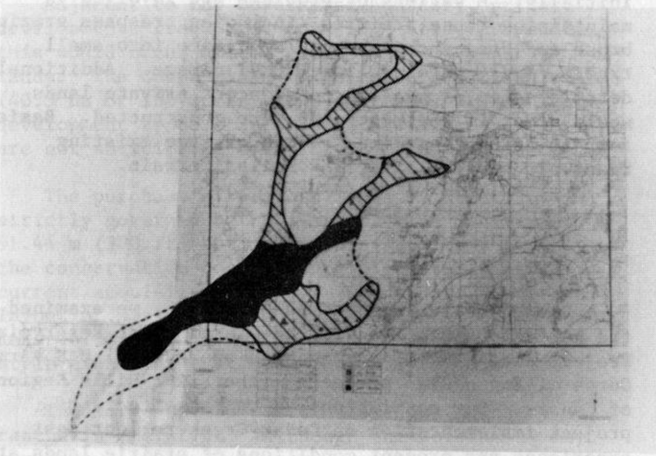


Fig. 3. Prairie corridors map shown superimposed on the stands map.

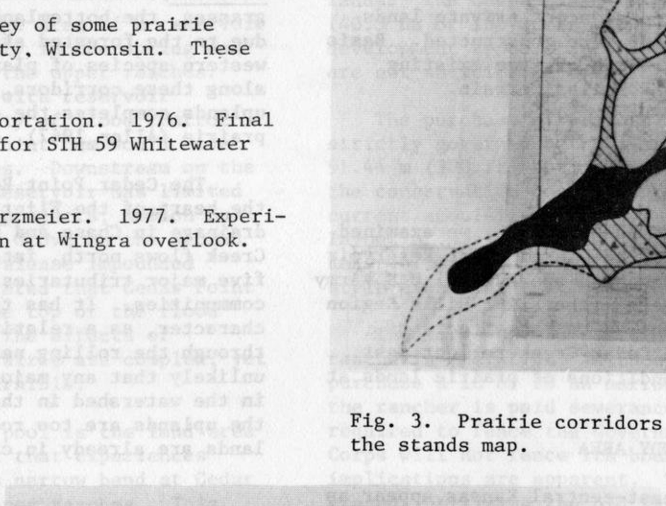


Fig. 4. Fire release of big bluestem grass (Andropogon gerardi) on the left half of photo; weedy forbs on the right unburned portion (January 1977).

EFFECTS OF A WATER RESOURCE DEVELOPMENT PROJECT ON NATIVE PRAIRIE IN THE FLINT HILLS OF KANSAS

George Harrington
Division of Ecological Services
U.S. Fish and Wildlife Service
Kansas City, Missouri

and

Stephen Capel
South-Central Regional Office
Kansas Forestry, Fish and Game Commission
Newton, Kansas

ABSTRACT

The probable adverse effects to 1744 ha of native priaire at a 4050 ha water resources project near Florence, Kansas, is discussed. About 430 ha of prairie would be permanently flooded or destroyed by construction activities. Approximately 405 ha of prairie in the flood pool area would be significantly altered by periodic inundation. Peripheral project lands involve 908 ha of prairie, of which 243 ha would be adversely affected by installation and maintenance of recreational facilities, leaving 664 ha of prairie intact. Of the total 1744 ha of native prairie in the project area, only 664 ha would remain undamaged initially. A variety of problems are involved in maintaining these prairies, including trespass grazing, brush and tree encroachment, severance into small tracts, and 4-wheel vehicle (ORV) damage. Additional deterioration of prairie on adjacent private lands would occur if the reservoir were constructed. Basis for the assumptions is a review of some existing reservoir project sites in similar terrain.

INTRODUCTION

During fall, 1975 and summer, 1976, we examined the native prairie lands at the Cedar Point Reservoir Project site as well as lands on operational U.S. Army Corps of Engineers' projects in the Flint Hills Region of Kansas. Our conclusions as to the effects of project implementation on Cedar Creek reflect past experience and present conditions of prairie lands at the operational projects.

STUDY AREA

The Flint Hills of east-central Kansas appear as a large, linear north-south block of land, roughly covering 45,770 km^2 (17,500 mi^2) of which 364,230 ha (900,000 acres) are native prairie. Since the Cedar Point Reservoir Project is located near the center of this area, we confined our study to the Corps' projects generally between Newton and Yates Center, Kansas. The projects visited were Toronto, Fall River, El Dorado, Marion, Melvern and Pomona Reservoirs.

The study area has a rolling topography with east-facing escarpments underlain with chert and limestone rocks. The climate is characterized by irregular precipitation, wide seasonal temperature ranges, high evaporation rates, frequent droughts, and persistent winds. The soils are generally shallow and rocky, although bottomland soils are deep and fertile. Bottomland areas are cultivated for wheat, milo, soybeans, corn and domestic hays. The uplands have primarily been maintained as native prairie for pasture, giving national significance to the region (U.S. Dept. Int. 1975). Cattle ranching is the traditional use. Controlled spring burning and seasonal grazing are the principal range management practices. Numerous, scattered stock ponds occur in the Flint hills.

Dominant vegetation of the uplands are grasses, i.e. little bluestem (Andropogon scoparius), switch grass (Panicum virgatum), Indian grass (Sorghastrum nutans), big bluestem (Andropogon gerardii), and side-oats grama (Bouteloua curtipendula). Common perennial forbs are lead plant (Amorpha canescens), cobaea penstemon (Penstemon cobaea), pitcher sage (Salvia azurea), blue wild indigo (Baptisia minor), many flower scurfpea (Psoralea tenuiflora), tall gayfeather (Liatris scariosa), compassplant (Silphium laciniatum), purple prairieclover (Petalostemum purpureum), and butterfly milkweed (Asclepias tuberosa). Aside from the domestic crops and tame grasses, the bottomland natural resources are diverse, due to the forested stream borders. Eastern and western species of plants and wildlife are found along these corridors. Their interspersion with the uplands completes the ecological complexity of the prairie (Allen 1967).

The Cedar Point Reservoir Project is located in the heart of the Flint Hills along the Cedar Creek drainage in Chase and Marion Counties, Kansas. Cedar Creek flows north, into the Cottonwood River, from five major tributaries rising out of native prairie communities. It has the full complement of scenic character, as a relatively unspoiled stream meandering through the rolling native prairie hills. It is unlikely that any major land use changes would occur in the watershed in the foreseeable future because the uplands are too rocky, and any tillable bottomlands are already in cultivation.

METHODS

During the fall, 1975, representatives of the U.S. Fish and Wildlife Service, and the Kansas Forestry, Fish and Game Commission, evaluated the terrestrial habitats that would be affected by the Cedar Point Reservoir Project. The team used the Fish and Wildlife Service's new methodology, the Ecological Planning and Evaluation Procedures, for the assessment. A value judgment was made using a numerical rating between 1 and 10 (low to high) reflecting the existing condition of the habitat type and its potential carrying capacity for wildlife.

The difference in the assigned value and the potential (10) is a measure of the amount of improvement that habitat could receive through intensive wildlife management. Using random samples of specific habitats, an average value for that particular habitat was calculated. Interpretation of aerial photographs completes the determination of the total area of the habitat type. The team rated overall native grassland at the site at 6.2. The aerial photo interpretation identified 429.6 ha (1,061.2 acres) of native grassland that would be lost to the project and 1314.5 ha (3,246.9 acres) that would be adversely affected by the project's operation and maintenance. The native grassland lost to the project is located within the conservation pool and the dam and spillway. Those areas adversely affected are the flood pool, recreation areas, peripheral project lands and adjacent non-project lands.

Comparisons using past performance are worthwhile measuring devices when attempting a prediction. The authors felt that examining some operational projects would strengthen our contentions. Early in summer, 1976, we toured six reservoirs in the general vicinity of the Cedar Point Reservoir Project. We were primarily concerned with the effects of the operation of the project on the flood pool and peripheral prairie lands. We also noted the private development that had occurred on adjacent non-project lands.

RESULTS AND DISCUSSION

The land areas used for dam construction and the conservation pool are lost to the project. Total grassland affected by these features at Cedar Point Reservoir would be 429.6 ha (1061.2 acres). Prediction of effects must then be made for those areas that are periodically flooded, possibly mismanaged, or that could be encroached upon by private development.

Portions of the flood storage area of a reservoir are usually inundated periodically in the spring and fall. Sediment is deposited in the upper reaches. The period of inundation varies with reservoir release schedules and the priority of flood control in the drainage system. Cedar Point Dam would have low priority flood water releases. Downstream on the Neosho River, the John Redmond Reservoir has limited flood storage; the two upstream projects, Marion on the Cottonwood River and Council Grove on the Neosho River, have higher priority to release impounded floodwater. The Corps has indicated that Cedar Point Reservoir could be at or near the top of the flood pool for long periods of time. The effects of periodic inundation of native prairie are complex, yet the end results are easily discernible.

The 5-year frequency flood pool is the land area just above the conservation pool that experiences routine flooding. It would be a narrow band at Cedar Point Reservoir except in the upper reaches. This entire area will lose all native grassland species and tend to support such pioneer species as eastern cottonwood (Populus deltoides), willows (Salix spp.), boxelder (Acer negundo), smartweeds (Polygonum spp.), Johnson grass (Sorghum halepense), sweetclovers (Melilotus spp.), ragweeds (Ambrosia spp.) and other annual weeds.

On several projects we visited, we found fairly intact prairie in the upper half of the reservoir's flood pool. Major changes in prairie species composition occur in the lower half of the flood pool to the 5-year flood frequency elevation. We believe that this would not occur at Cedar Point Reservoir. Intact prairie remaining in the flood pool area after several years of reservoir operation would be negligible. The most outstanding characterisitc is the rapid disappearance of most perennial native forbs. Most native forbs apparently cannot withstand a supersaturated root zone. Some perennial sunflowers plus some increaser forbs hold out better than most of the decreaser forbs. Native grasses also succumb to inundation, but much more slowly, although the exception, switchgrass, remains, enduring up to 6 months of constant flooding. Purpletop (Tridens flavus) is an increaser grass with almost equal flooding tolerance.

At Cedar Point Reservoir we predict the flood storage pool will have drastically altered prairie vegetation after several years of operation. The flood pool involves 404.8 ha (1,000 acres) of prairie.

The largest portion of native prairie at Cedar Point Reservoir occurs on the unflooded, peripheral project lands. Total area of this segment of grassland habitat is 907.5 ha (2241.5 acres). Two recreational sites are planned for these lands on either side of the lower main pool area which is almost entirely vegetated with native prairie. Trees are planted, facilities constructed, and most of the grounds are manicured to enhance the reservoir-associated outdoor experience; these land use changes result in further losses of prairie lands to the project. We envision major adverse effects to approximately 243 ha (600 acres) of prairie due to the recreational developments.

Adjacent to the Government boundary, private developments frequently move in. At Cedar Point, this would occur almost exclusively on prairie lands. The Corps plans to purchase additional lands (40.5 ha or 100 acres) to buffer those areas where development appears inevitable. Private developments are not anticipated on a large scale.

The purchase of project lands by the Corps is strictly governed by regulation. The minimum of 91.44 m (300 ft) horizontal distance from the top of the conservation pool dictates, generally, the current acquisition policy. Due to the topographic layout of most projects (and especially Cedar Point Reservoir), this leaves a rather narrow purchased strip alongside the flood pool.

The large upland pastures are the mainstay of a rancher's operation. Although the Government may purchase a 10 or 20 ha narrow strip of his pasture, the rancher is paid severance for this, yet is not required to fence the Government boundary. The Corps will not fence its boundaries either. The implications are apparent. The land is trespass grazed, utilizing the old fence on the old property lines. Compatible grazing results in continuing the prairie association. But commonly this is the exception, not the rule. Many stock ponds are also located along this gentle slope that is purchased. Salting and winter feeding often take place on the Government land. The prairie usually is trampled and abused on these narrow strips.

Fencing the area by the Kansas Fish and Game Commission or other agencies is often impractical from an economic standpoint. Few hectares are protected by comparison to the length of fence required. If grazing is curtailed, brush growth would be stimulated where site and climate conditions are favorable (Cosby 1975). Fire in some cases cannot be employed to set back succession, because of inadequate firegards and the potential for escape to the larger pastures. Brush control on the strips is difficult because the Kansas Fish and Game Commission is reluctant to use herbicides. Without fencing, burning would only entice cattle into overgrazing the narrow strips. Generally, adjoining landowners have not been burning their pastures. So, it is apparent that grassland falling into this category is often adversely affected. About 75% of the narrow strips of peripheral lands in native grassland are inevitably mismanaged on operational projects. It appears that this would be likely at Cedar Point Reservoir unless the Corps' policy changes.

Another problem is destruction of prairie by four-wheel drive vehicles. Reservoirs are focal points of recreational activity, and four-wheel driving or cross country touring is rising in popularity as a recreational pursuit. In many instances the prairies suffer from constant off-the-road traffic. It is difficult, however, to measure the effects of this particular activity.

The standard procedure on most Corps' reservoirs is that the state game and fish agency takes license to the lands in the upper reaches of the project. Most segmented lands around recreation areas, the dam, or access roads in the lower reaches fall under the Corps' management. In the past, the Corps leased these areas for agriculture or neglected them. Presently, the Corps develops management "prescriptions" for all these land parcels. As recently as last year, fire was brought into the system of managing prescription areas of grassland on Corps' projects.

Our last finding was that mismanagement of pasture can take place during the construction period after the Government has bought the land. The principal reason for this is that the prior landowner wants to get the most he can from the condemned lands he once owned. He is generally granted a lease for grazing until the reservoir becomes operational. Most of the damage occurs the first year when the prior owner is granted a priority lease. The Corps has shown a willingness to improve interim grazing leases by including specific clauses regulating cattle numbers and duration of grazing. Their limitations reflect the relative lack of expertise on range management principles at the project's field office.

RECOMMENDATIONS

Apparently the Corps will continue to build and operate reservoirs in the Flint Hills of Kansas. With some modification of their current policies, native prairie on these projects can be maintained. Since the public actually owns these reservoirs, they should take an active role in project planning as well as in the operation and maintenance of the projects. The authors offer these suggestions to amend present Corps procedures:

a. Fencing project boundaries be included as a project cost, whether it be identified as a severance cost or a direct mitigation expense.

b. Interim licenses for management by the Kansas Fish and Game Commission be granted as soon as project land purchases expand beyond the construction zone.

c. Purchase of project lands be flexible to allow the Corps to buy land along existing boundaries or roadways.

d. Solicit private citizens with expertise in prairie management to assist the Corps in review and implementation of native prairie management.

LITERATURE CITED

Allen, D. L. 1967. The life of prairies and plains. McGraw-Hill, New York. 282 p.

Cosby, H. E. 1975. Range ecosystem management for natural areas. U.S. Fish and Wildlife Service, Denver, Colorado. 14 p.

United States Department of the Interior, National Park Service. 1975. Preliminary environmental assessment - alternate study areas - proposed prairie national park. U.S. Gov. Printing Off., Washington, D.C. 65 p.

CONTROLLING EXPERIMENTAL BLUESTEM PRAIRIE FIRES

Lloyd C. Hulbert

Konza Prairie Research Natural Area
Division of Biology
Kansas State University
Manhattan, Kansas 66506

ABSTRACT

Procedures are described that have been developed for experimental burning of 10 to 20 ha watersheds on Konza Prairie Research Natural Area in bluestem prairie near Manhattan, Kansas. First the fuel supply is reduced by July mowing and haying. In the autumn or spring fire guards about one meter wide are burned around the boundary of each watershed by burning between strips of metal edged with a band of chains which are pulled behind a tractor. Fire swatters and power water pumps are used to extinguish any fire that is left as the metal strips pass. At the time of the main burn two crews proceed in opposite directions from the middle of the leeward side. The fire is started next to the fire guard, with the crews ready in case the fire escapes. By the time the fire is started on the windward side, the fire has burned some distance back from the fire guard on the leeward side. The system works well in reasonable weather conditions.

STUDY AREA

The 370 ha Konza Prairie Research Natural Area, 16 km south of Manhattan, Kansas, was purchased by The Nature Conservancy and given to the Kansas State University Endowment Association for ecological research. The management objective is to approximate the pre-settlement bluestem (tallgrass) prairie.

Because fire was an important part of the pre-settlement prairie ecosystem, the area has been divided into watershed units which are burned at 1-, 2-, 4-, and 10-year intervals, burned after unusually wet years, and unburned. The area is ungrazed by large herbivores, except for a few deer, and so fuel is greater than in bluestem prairie grazed by livestock. Having many kilometers of perimeter around four replications of the six burning treatments in ungrazed prairie makes controlled burning a challenge.

PROCEDURE

A necessity in controlled burning is to establish a fire guard around the area that is to be burned. We make fire guards by burning strips around the perimeters of the areas to be burned. Because ungrazed tall grass can produce such a hot fire that one cannot get near it, the fuel must be reduced before burning a fire guard. This we accomplish by mowing. The old grass should not be left in place after mowing, because it will compact on the soil surface and then not burn quickly and completely. Therefore we find it best to mow in late July and remove the mowed forage for hay. Besides getting rid of the material which hinders fire control, we get some income from the hay to partially offset the cost of burning. The grass regrows during the several weeks remaining in the growing season after mowing, producing an amount that will burn rather well but not be too hot to work nearby.

We ruled out cultivation for making fire guards because it would result in serious erosion on the slopes as well as encourage annual weed invasion. We make fire guards by burning a strip about a meter wide. There is over 20 km of boundary, and so, even though not all 20 km need be burned each year, the distance is enough to demand an efficient method of making fire guards.

A local rancher told of helping another rancher fight fires by pulling an old rug in front of hot spots to slow the fire and give more time to stop it. From this idea I gradually developed a system employing two strips of metal about 82 cm wide and 16.5 m long. The metal strips, about a meter apart, are pulled by a tractor. The 26-gage sheet metal, cut into pieces and wired together to facilitate bending, rides on top of the grass, so we added a 6-strand band of single jack chain along the inner edge of each metal strip (Fig. 1). The chain rubs against the soil surface. A person carrying a drip torch lights the fire at the front end, so that as the strips are pulled along the fire burns to the band of chain. When conditions are proper the fires goes out when it reaches the chain.

The idea is, of course, to pull the two strips of metal and chain along, set fire at the front end, and watch the fire go out as it burns to the chain bands (Fig. 2). Fortunately it does work that way frequently. However, fire burns under the chain and metal where the surface is rough, due to rocks or due to depressions like old cow trails, and sometimes fire persists after the metal has passed.

Crossbands of chain were added on the underside of the metal strips at every other joint, about 1 m apart. As they drag along, these cross bands extinguish many of the small flames that get under the metal. Because of this it is best to keep moving along. When it is necessary to stop, as when those behind cannot keep up, the chance of fire burning under the metal and coming out on the outside edges is much increased.

Sometimes the grass does not burn rapidly, and flames may persist after the metal strips have passed. It is essential that means be at hand to extinguish all such fires. Fire swatters are excellent for small flames, and we use them regularly. However, if a gust of wind carries the flame into deep grass beyond the mowed strip, fire swatters are of little or no use. Therefore we have three power pumps, one in a trailer behind the tractor, the other pulled along behind two all-terrain vehicles. Rubber nylon bags holding up to 400 l of water and gasoline-powered pumps with hoses 8 to 15 m long are used. A fine spray is used at the rear end of the metal strips if the fire is not out by the time the metal passes. Two pumps are kept in reserve for emergencies.

It is essential, but hard for the inexperienced to appreciate, to have two workers scattered far back of the metal strips. One to three persons, depending on the wind velocity, need to be just back of the metal. In addition another person needs to be something like 25 m back, and another 50 to 100 m behind. Occasionally a flame will persist, under a rock or in some other way where it is not noticed for several minutes, and then flare up and quickly spread. Such a fire can appear five or even ten minutes after burning that part of the fire guard. If someone is watching nearby they can put it out while it is very small, but if it is first noticed from 100 m or more away the fire can get large before one can get back to it. Workers often feel they should be up helping with the action instead of just "lolling along" doing "nothing", and since the fires they are guarding against are infrequent, they may feel unnecessary. They tend to move too close to the rest of the crew. Actually they are as important as any of the crew, as they can make the difference between a safe burn and having a fire escape and burn a large area.

These fire guards can be burned days or weeks ahead of the date for the main burn, so that all the areas to be burned can be burned at the desired time. For late spring burns it is helpful to make the fire guards some time ahead because the bare soil will warm earlier than in unburned areas, which will stimulate early growth of grass on the fire guard. This early green growth adds to the effectiveness of the guard.

The most difficult task is finished when the fire guards are completed, because in reasonable weather conditions, with winds up to 15 or 20 km per hour, a one meter wide fire guard that is devoid of fuel to carry a fire will make burning safe if properly done.

The watersheds are burned by starting on the leeward side, so that the fire starts against the wind (Fig. 3). It is best to have two crews, each with a torchperson to start the fire and a backup crew to watch and be ready to put out any fire that might cross the fire guard. The crew needs to be trained to space themselves behind the torch, as discussed above. The torchpersons start the fire at the edge of the fire guard as they proceed around the area. By the time they have arrived at the windward side the fire will have burned several meters from the fire guard on the leeward side, thus providing a safe barrier to the fire moving rapidly with the wind (Fig. 4).

It would be possible to burn the entire area against the wind, resulting in a much slower fire with lower flames. We do not recommend this for two reasons. One is that winds sometimes shift direction. Normally the fire guard would still hold unless wind velocities are high but it certainly would be less safe than having the fire started at the fire guard and burn away from it. Secondly, observations of prairie fires indicate that fire burning with the wind produces less heat at the soil surface than fire burning against the wind, and fire with the wind may be more effective in killing trees and shrubs.

Because fuel conditions and wind can change unpredictably, burning vegetation contains threats of trouble no matter how careful one is. If one could always burn fire guards when the wind is consistently less than 8 to 10 km per hour, one could assure that the fire would not get away if one used reasonable procedures. But in prairie, wind is seldom consistently that low. Therefore one must always have more fire fighting potential than is normally needed in order to handle the sudden gust, the breakdown of equipment, or the human errors that do occur. The system described above, although not guaranteed safe, has proven very successful for us in burning several kilometers of fire guards per year.

ACKNOWLEDGEMENTS

The work reported herein was supported by the Kansas Agricultural Experiment Station.

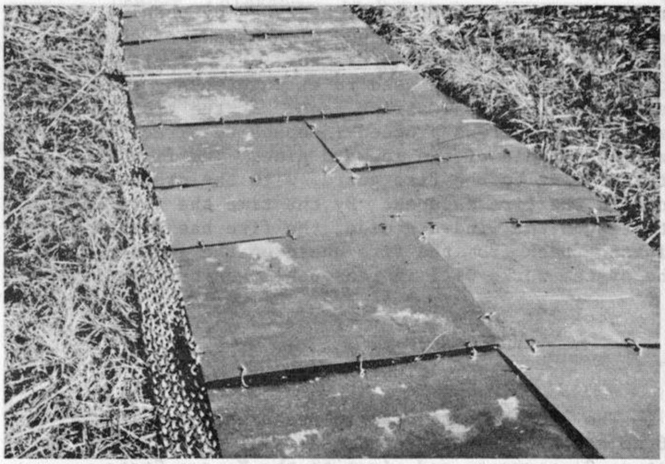


Fig. 1. Portion of one metal strip showing the metal squares we wired together and the six-stranded band of chain on the inner edge.

Fig. 2. Method of burning fire guards. The fire is being started with a drip torch by the person at the right as the metal strips are pulled along. The band of chain usually prevents the fire from burning under the metal. One worker with a fire swatter and another with a hose from a power pump on an all-terrain vehicle are ready to extinguish any fire left behind the metal strips.

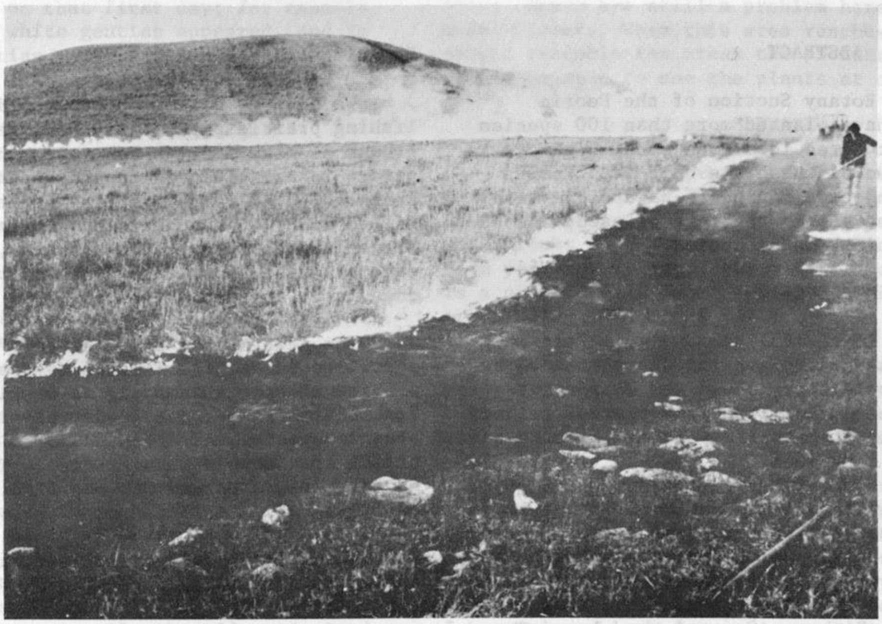


Fig. 3. Starting to burn an area around which a fire guard had been made. A person with a drip torch has started on the leeward side next to the fire guard so the fire will burn a wide strip before fire is started on the windward side.

Fig. 4. Completing a burn. The fire was started first on the leeward side out of the photograph to the left. Now the two torchbearers have met on the windward side and the fire is beginning to move rapidly across the area.

ESTABLISHING PRAIRIE VEGETATION ALONG HIGHWAYS IN THE PEORIA AREA

Margaret Irene Cull
803 N. Asland Avenue
Peoria, Illinois 61604

ABSTRACT

Members of the Botany Section of the Peoria Academy of Science have planted more than 100 species of prairie plants at three locations along highways in the Peoria area. Two of these are on I-74. Peoria District Highway Landscape Engineers have cooperated. The location of these plots, the methods used, and the results up to this time are discussed.

INTRODUCTION

Since Illinois is the Prairie State, I felt that prairie vegetation should be growing along some of our highways so that people today could see samples of vegetation the pioneers saw. For many years I talked about this, but I didn't know the persons to contact about starting such a project.

Finally, in July 1966 I met the Peoria District highway landscape engineer and his assistant. I presented my plan for prairie vegetation along the highways for beauty all year, for low-cost maintenance of the right-of-way, and for preserving our heritage for future generations. Both men favored the plan. They had thought about establishing prairie flora along our highways but had not done anything about it. They needed people who could identify the plants, would know the desirable conditions for the different species, and could check the experimental area frequently. As Botany Section Leader of the Peoria Academy of Science, I let them know that our Section would like an area for an experimental planting of prairie flora.

PROCEDURE

The First Plot

We were assigned a small area on the south side of the recently completed Interstate 74. If the project succeeded it was to serve as a nursery for plants to be moved to other areas along Illinois highways. The engineers agreed to mark the assigned area and not mow it for several years.

The experimental plot is 7½ miles (12.07 km) west of the University Street interchange in Peoria, Illinois. It is 200 feet (61 m) long by 50 feet (15.24 m) wide, flat and below the level of the road. It has been graded so that all the water does not drain off immediately after a rain. The flat ground is at the top of a bluff and slopes slightly toward a stream at the eastern end. Near the middle of the south side and across the fence is a stand of trees. The soil on most of the area is hard-packed clay subsoil. The remainder contains some sand.

From that July until November the Section members collected seeds of prairie plants. See Table 1. On a Saturday morning in mid-November these seeds, as well as some plants, were brought to the site. Some did not belong on a prairie, but we planted them to keep the donors happy. Most of these unsuitable plants have disappeared now. We received publicity about this project from the beginning. A news photographer, a reporter, and the assistant highway landscape engineer were there that first day. About every two years there is a feature article about our project.

Planting the First Plot

We did not follow the approved methods for establishing prairie plantings. We merely loosened the ground at many small spots, using hoes and steel garden rakes. Then we broadcast the seeds on these spots. The holes dug for the donated clumps were filled with water containing one tablespoon of the Transplantone* per gallon of water, a clump placed in each of these, soil filled in and packed down. Two days later the ground froze.

The next spring we received a large sack of scarified seeds of a mixture of prairie plants. We planted these the same way as we planted in the fall. Frequently since then, seeds, plants, and bulbs of prairie species have been added to the area. A total of 103 species has been planted. The plot has not been mowed. It was burned for the first time in the spring of 1976.

When the landscape engineer was transferred to Springfield in 1968 we thought the project might end, but it didn't.

Plot 2

In 1971, five years after the first planting, the new landscape engineer asked if our group would like another area for planting. This would be at a rest area on Route 29, northeast of Chillicothe, Illinois. It would be a safer place for tourists to see the plants. The highway men would prepare the ground and add peat moss and commercial fertilizer to it. We were to plant only the shorter prairie plants because the place might be unsafe if tall plants were used. Here seeds were planted in rows. Occasionally since then more species have been seeded on or transplanted to the area. Every fall this plot is mowed very short.

Plot 3

Three years ago the landscape engineer told us we could establish prairie on a 5-acre plot at the Mackinaw River rest area on the north side of I-74, east of Morton, Illinois. His men would prepare the soil and plant the grasses, and our group could do the rest. I suggested that large clumps of prairie grasses be moved from an area that would be destroyed by a by-pass. About 20 clumps with the associated forbs were moved to the plot. Seed of prairie grasses, mostly little bluestem, was sown here. Also seeds of 71 species have been planted on this area.

Seedlings of 17 species were donated, and some species were transplanted from areas that were being destroyed (for gardens and crops, and by construction projects). The plot was burned in Spring 1976.

RESULTS

Plot 1

This plot appears natural now. Of course weeds were plentiful during the first years, especially

---

*Mention of brand name does not represent an endorsement of the product.

common ragweed. When the area was checked during the early growing seasons, different plants were identified almost every two weeks. Occasionally we still find species we sowed on that first day; for example, in 1974 the yellowish white gentian appeared, and in 1975, the prairie gentian. The grasses have increased in height and size of clumps since the beginning. Transplanted forbs have grown, flowered, and produced seed each year, but they did not multiply much. This year these plants appear to be seeding the area. Where there had been only one or two stalks on a plant there are several stalks now. Ninety-two species have been identified here.

Plot 2

Thirty-five species are established on this plot. The first year the plants were gigantic; e.g., partridge peas were 2½ feet (.76 m) tall, but now they are normal size. The weeds thrived, but we were able to control them. However, crown vetch has been and still is a serious problem. One time, after some of the desirable species were transplanted here, the area was mowed very short, so those species have not reappeared. Now a wooden fence has been built around this plot, and we can plant whatever we wish. The row effect is still there. Because of this and the crown vetch, we would like to dig everything in spring and replant to produce a more natural-looking prairie. Absence of prairie grasses spoils the effect desired.

Plot 3

Seventy-two species have been planted on this area. Weeds are still a problem here, as is yellow sweet clover. When this area reaches its peak it should resemble the areas the pioneers saw, and people should be able to see the plants at close range.

SUMMARY

Three plots of prairie have been established along highways of Central Illinois, two of them along I-74. The most species, 92, are thriving on the oldest plot, which looks like a prairie should look. Plot 2 after five years still shows the planted row effect. There is a problem with crown vetch. However, 35 species are growing on this plot.

The largest plot, 5 acres, has a good stand of prairie grasses, but weeds are still plentiful. Seventy-one species of forbs have been planted on the area, some from seed and some by transplants.

No one had faith in our first prairie planting. About every other year in the local paper a feature story has stated that if this plot thrives and increases, prairie can be established anywhere. The area looks more like a prairie each year. People who read about it or hear about it ask to see our planting. I have always been sure this would look like an original prairie some day.

Table 1. Species Planted and Thriving on the 3 Roadside Plots near Peoria, Illinois. (S = seeds; V = volunteers; B = bulbs; P = plants)

Name	First Plot Started from	First Plot Growing	Second Plot Started from	Second Plot Growing	Third Plot Started from	Third Plot Growing
Big Bluestem Andropogon gerardi Vitman	S-P	X			P	X
Little Bluestem Andropogon scoparius Michx.	S	X			S	X
Indian Grass Sorghastrum nutans (L.) Nash.	S	X			P	X
Tall Panic Grass Panicum virgatum L.		X				
Hairy Panic Grass Panicum lanuginosum Ell. var. fasciculatum (Torr) Fisch. & Lall.		X				
Purple Top Triodia flava (L.) Smyth forma cuprea (Jacq.) Fosberg	V	X	V	X	P	X
Cord Grass Spartina pectinata Link	V	X				
Blue Grass Poa pratensis L.	V	X	V	X	V	X
Spiderwort Tradescantia ohioensis Raf.	P	X	S	X	S	X
Wild Garlic Allium canadense L.	B	X	B	X	B	X
Wild Hyacinth Camassia scilloides (Raf.) Cory			B			
Turk's Cap Lily Lilium michiganense Farwell	B					
False Solomon's Seal Smilacina racemosa (L.) Desf.	V	X				
Starry Solomon's Seal Smilacina stellata (L.) Desf.	S	X			S	
Yellow Star Grass Hypoxis hirsuta (L.) Coville	S	X	P	X	S	X

Table 1. continued.

Name	First Plot Started from	First Plot Growing	Second Plot Started from	Second Plot Growing	Third Plot Started from	Third Plot Growing
Blackberry Lily Belamcanda chinensis (L.) DC.	P	X				
Blue-Eyed Grass Sisyrinchium angustifolium Michx.	S-P	X	S	X	S-P	X
Short-Stemmed Iris Iris brevicaulis Raf.	P	X				
Wild Ginger Asarum canadense L.	P	X				
Meadow Rice Thalictrum dasycarpum Fisch. & Lall.	S-P	X			S	
Canada Anemone Anemone canadensis L.	P	X	P	X	P	X
Thimbleweed Anemone virginiana L.	P	X	S	X	S	X
Wild Delphinium Delphinium tricorne Michx.	P					
Long-Headed Thimbleweed Anemone cylindrica Gray	P	X			S	
Meadow-Sweet Spirea alba Du Roi	P					
Wild Strawberry Fragaria virginiana Duchesne	V	X	P	X	P	X
Canada Cinquefoil Potentilla canadensis L.	V	X	V	X	S	X
Double-Flowered Cinquefoil Potentilla sp.	P	X			P	
Tall Cinquefoil Potentilla arguta Pursh	S	X	S	X	S	
Queen-of-the-Prairie Filipendula rubra (Hill) Robins.	P	X				
Prairie Smoke Geum triflorum Pursh.	P	X				
Wild Rose Rosa carolina L.	V	X				
Sensitive Plant Desmanthus illinoensis (Michx) MacM.	S	X	S	X	S	
Partridge Pea Cassia fasciculata Michx.	S	X	S	X	S	X
White False Indigo Baptisia leucantha T. and G.	S	X	S	X	S-P	X
--------------- Psoralea onobrychis Nutt.	V	X			S	X
Lead Plant Amorpha canescens Pursh	S-P	X			S-P	
Purple Prairie Clover Petalostemum purpurea (Vent) Rydb.	S	X	S	X	S	X
White Prairie Clover Petalostemum candidum (Willd.) Michx.	S	X	S	X	S	X
Tick Trefoil Desmodium canadense (L.) DC.	S	X				
Tick Trefoil Desmodium sp.	S	X				
Bur Clover Lespedeza capitata Michx.	S	X	S	X	S	X
Hog Peanut Amphicarpa bracteata (L.) Fern.	V	X				
Lupine Lupinus perennis L.					P	
Violet Wood Sorrell Oxalis violacea L.	V	X				
Wild Geranium Geranium maculatum (L.)	V	X				
Milkwort Polygala polygama Walt. var. obtusata Chodat	S	X				

Table 1. continued.

Name	First Plot		Second Plot		Third Plot	
	Started from	Growing	Started from	Growing	Started from	Growing
Seneca Snakeroot Polygala senega L.	S				S	
Flowering Spurge Euphorbia corollata L.	S	X	S	X	S	X
New Jersey Tea Ceanothus americana L.	V	X			S	
Arrow-Leaved Violet Viola sagittata Ait.	S	X				
Blue Violet Viola papilionacea Pursh.			P	X	S	X
Rattlesnake Master Eryngium yuccifolium Michx.	S	X	S-P	X	S-P	X
Golden Alexander Zizia aptera (Gray) Fern.	P	X				
Golden Alexander Zizia aurea (L.) W. D. J. Koch	P	X	P	X		
Yellow Pimpernel Taenidium integerrima (L.) Drude	S	X	S	X	S	X
Shooting Star Dodecatheon meadia L.	S-P	X	S-P		S-P	X
Bush Gentian Gentiana puberula Michx.	S	X			S	
Yellowish White Gentian Gentiana flavida Gray	S	S			S-P	
Bottle Gentian Gentiana andrewsii Griseb.	S				S	
Blue Milkweed Amsonia tabernaemontana Walt.	P	X				
Butterfly Weed Asclepias tuberosa L.	S		S	X	S-P	X
Common Milkweed Asclepias syriaca L.			S	X	V	X
Whorled Milkweed Asclepias verticillata L.	S	X	V	X	V	X
Low Bindweed Convolvulus spithamaeus L.	S	X				
Alumroot Heuchera richardsonii R. Br.	S				S-P	
Jacob's Ladder Polemonium reptans L.	P	X				
Blue Phlox Phlox divaricata L.	P	X				
Prairie Phlox Phlox pilosa L.	S-P	X			S-P	X
Virginia Bluebell Mertensia virginica (L.) Pers.	P	X				
Hoary Puccoon Lithospermum canescens (Michx.) Lehm.	S				S-P	
Yellow Puccoon Lithospermum incisum Lehm					P	
Wild Bergamot Monarda fistulosa L.	S	X			S	
Mountain Mint Pycnanthemum virginianum Durand & Jackson	S	X			S	
Ground Cherry Physalis virginiana Mill.	S	X			V	X
Hairy Penstemon Penstemon hirsutus (L.) Willd.	S	X	S	X	S	X
Kittentails Wulfenia bullii (Eat.) Barnh.	P					
Culver's Root Veronicastrum virginicum (L.) Farw.	P	X			S-P	

Table 1. continued.

Name	First Plot		Second Plot		Third Plot	
	Started from	Growing	Started from	Growing	Started from	Growing
False Dragonhead						
Physostegia virginiana (L.) Benth.			S		S-P	
Gerardia						
Gerardia tenuifolia Vahl.			S	X		X
Indian Paint Brush						
Castilleja coccinea (L.) Spreng.	S	X	S		S	
Ruellia						
Ruellia humilis Nutt.	S	X				
Northern Bedstraw						
Galium boreale L.	S-P					
Spiked Lobelia						
Lobelia spicata Lam.	S	X			X	
Ironweed						
Vernonia missurica Raf.	S			X	P	X
Tall Boneset						
Eupatorium serotinum Michx.						X
Blazing Star						
Liatris aspera Michx.	S-P	X	P	X	S-P	X
Blazing Star						
Liatris pycnostachya Michx.	P	X			V	
Early Goldenrod						
Solidago nemoralis Ait.	S	X			S-P	X
Showy Goldenrod						
Solidago speciosa Nutt.	S	X			X	X
Canada Goldenrod						
Solidago canadensis L.	S	X			P	X
Tall Goldenrod						
Solidago altissima L.	S	X			P	X
Stiff Goldenrod						
Solidago rigida L.	S	X	S	X	S-P	X
Frost Aster						
Aster pilosus Willd.	S	X	S		V	X
Heath Aster						
Aster ericoides L.	S	X	S	X	V	X
Azur Aster						
Aster azureus Lindl.	S				S	
Smooth Aster						
Aster laevis L.	S				S	
New England Aster						
Aster nova-angliae L.					P	
Pussy Toes						
Antennaria plantaginifolia (L.) Hook.	S	X				
Pearly Everlasting						
Gnaphalium obtusifolium L.	S	X			S	X
Compass Plant						
Silphium laciniatum L.	S-P	X	P		S	
Prairie Dock						
Silphium terebinthinaceum Jacq.	S-P	X	P		S-P	
Wild Quinine						
Parthenium integrifolium L.	S-P	X			S-P	
Yellow Coneflower						
Rudbeckia laciniata L.	S	X	S	X	S-P	X
Brown-Eyed Susan						
Rudbeckia hirta L.	S	X	S	X	S	X
Pale Coneflower						
Echinacea pallida Nutt.	S-P	X	S	X	S-P	X
Purple Coneflower						
Echinacea purpurea (L.) Moench	S	X			S	
Western Sunflower						
Helianthus occidentalis Riddell	S	X	S	X		
Hairy Sunflower						
Helianthus mollis Lam.	S	X				
Ox-Eye						
Heliopsis helianthoides (L.) Sweet	S	X			S	

Table 1. continued.

Name	First Plot Started from	First Plot Growing	Second Plot Started from	Second Plot Growing	Third Plot Started from	Third Plot Growing
Coreopsis						
Coreopsis palmata Nutt.	S-P	X	P	X	S-P	X
Tall Coreopsis						
Coreopsis triptera L.	S	X			S	
Ragwort						
Senecio plattensis Nutt.	S	X			S	
Hill's Thistle						
Cirsium hillii (Canby) Fern.	S	X			S-P	
False Dandelion						
Krigia biflora (Walt.) Blake	S	X	S	X	S-P	
Golden Aster						
Chrysopsis Bakeri Greene	S	X			S-P	X

LANDSCAPE ARCHITECTURE IN A HIGHWAY VEGETATION MANAGEMENT PLAN

Wayne Tipsword
District 7
District Landscape Architect
Illinois Department of Transportation
Effingham, Illinois 52401

ABSTRACT

This paper describes a method for designing and implementing a vegetation management plan for a four lane access-controlled highway in a rural midwestern environment. The method has been applied to several miles of interstate highways using aerial photography in the design process. Turf, Tall Grass and Forest are the three vegetation management types utilized.

The solution to the problem of vegetation management which I will describe is the product of District #7 Illinois Department of Transportation. This method does not represent official department policy rather it is what we believe to be an ideal concept which may have application elsewhere.

Assessment of today's activities must necessarily begin with a study of the beginnings which led to those activities. The earliest paved routes in Illinois, which were maintanied by the State Highway Division, were narrow paved roadways, usually 16 feet in width on 60-foot rights of way, earthen shoulders and grass-covered rights of way. Later the paved surfaces were expanded to 20 and 22 feet in width and eventually 24 feet and constructed on 80- to 100-foot turf-covered rights of way. The final stage of evolution in highway building (and the ultimate by today's standards) is the Federal Aid Interstate system built with two 24-foot pavements, paved shoulders, large interchanges encompassing 300-foot rights of way and taking approximately 40 acres of land per mile. Traditional methods of maintenance on narrow 60-foot rights of way included an annual mowing to prevent encroachment of tall weeds and woody vegetation onto the earthen shoulder. Sixty-foot rights of way contained the pavement, shoulder and drainage ditches, and mowing was essential to keep these areas operational.

Highway administrators and the general public developed the habit of seeing these rights of way mowed from fence line to fence line. With the addition of many miles of expanded Primary and new Interstate rountes on new locations, we eventually became aware of the fact that we were the managers of the single largest lawn area in the State of Illinois, running to some 345,972 acres (140,015 ha) mowed in 1975.

This staggering amount of lawn maintenance involved large fleets of equipment, many dollars worth of commodities, repair parts, and numerous manhours of input. These items are eventually translated to dollars, and in 1975 our per acre mowing cost in District 7 reached $10.88. Inflation continuously eroded away the dollars, and with no increase in revenues, we finally came to the realization that the only practical solution was to reduce the number of acres mowed. With complete lack of ingenuity, we reduced mowed areas by arbitrarily establishing a mow line at some specified distance from the edge of the pavement. Beyond this the areas were to be left standing in tall grasses. This basic plan was modified in special cases where site distance would be encroached upon and where adjacent and abutting land use was not compatible with our ragged foreground. Such locations were cemeteries, golf courses, parks and semi-urbanized areas. This led to considerable reduction in mowing costs but was totally unimaginative in aesthetic appeal. In the beginning considerable public outcry was experienced.

At approximately the same time this evolution was taking place in our maintenance operation, our landscape planting maintenance was falling behind. Cutbacks in funds, reduction in our personnel and lack of adequate equipment necessitated that we change our type of landscape and ornamental plantings away from the larger balled and burlap stock, which is almost completely dependent upon supplemental watering in order to survive the first two growing seasons after transplanting. In addition the masses of shrubs planted in beds are dependent upon cultivation and weed control for from two to four growing seasons after transplanting in order that they can become established and develop enough competitive growth to suppress weeds and grasses.

The objective, then, in the application of landscape architecture to the problem of highway vegetation management needed to be realistically altered. The vegetation types used to cover highway right of way areas are adequately funded at the time of original installation with almost zero funds being available for future maintenance after the initial contract period, which extends normally through two growing seasons. Past knowledge and experience indicated to the landscape section in District 7, which consisted of a landscape architect, forester, and plant ecologist, that the only woody plants that could be utilized in such a program would be small seedlings, usually under three years in age and 24" height. Conditions dictated that these plants would have to be selected for soil types, exposures, site condition and a species that would eventually be ecologically dominant. Species best suited for this application are not always indigenous.

With the definition of the problem, we coined a new description for the process in which we became involved. We called this the development of a planned vegetation management program in lieu of the conventional method of seeding, sodding, and landscaping. The realization that we were in the real estate management business is emphasized by the costs which are involved in purchasing, clearing, grading and topsoiling, seeding and mulching an acre of highway land in District 7, which totals approximately $3,000.00 per acre.

The process of developing a vegetation management program led us to the conclusion that there are basically four types of management areas to be utilized in the highway program (dealing only with Interstate highway type design). These are: critical slope areas, areas to be maintained in mowed turf, the portion which can be left to tall grasses and those areas that are in existing woodland, and other areas which can be converted to woody cover either overstory or intermediate woody covers. Critical slope areas are those too steep to mow, which should be covered with vigorous soil-holding plants that are aesthetically pleasing to the traveling public. Areas which are best maintained as mowed turf are intense man-managed systems such as interchanges, the median, urban sections and other areas adjoining private land use, which is most appropriate and compatible with a mowed turf. Areas which can be left in tall grasses are those intermediate areas which adjoin pasture land, hay fields, and in most cases, crop land. Areas which can be returned to woody cover are areas adjoining existing timber lands and wood lots and rough and rolling terrain where abutting land use is compatible.

Acceptance of this definition of the problem then leaves the designer with the task of developing and implementing a plan which will establish these areas, delineate them in the most aesthetically pleasing manner, and blend the areas together so they compliment the travel experience.

We have found from past experience that the scale of an Interstate highway and the speed of travel dictates that large masses and generous dimensions are most appropriate. This approach then tends to contain plant masses in large areas with no mowing between plants. This simplifies maintenance and mowing in turn. The first step in this operation is the establishment of a mowing limit line. This line delineates the areas to be mowed from those which will not be mowed. The line is placed on the plans and staked in the field by the landscape contractor. In 1970 we adopted this method of landscape design, and subsequent contract plans were prepared accordingly. Early attempts at establishing the mow line were done with small plastic flags on wires, but we soon came to know that if the mowing line was to remain an established fact throughout many seasons and numerous changes in personnel that it must be permanently established not only on the plans, but in the field on the ground. We therefore specify that the contractor furnish and install steel fence posts, painted a solid green color, as indicated on the plans.

The meandering mow line adds variety to the monotonous linear quality of rights of way and when skillfully done adds variety and interest throughout all seasons. The configuration of this line is used to open vistas, create meadows, enclose meadow-like areas, and its creation belongs to the arts rather than the science of highway building.

Once the mow line is established, two of the areas have been defined. Critical slopes have been eliminated from consideration earlier during the construction as these were seeded to permanent ground covers. Then the areas beyond the mow line fall into two categories. One is those areas which will be maintained in tall grasses left unmowed and the other are those areas which are in, or will be converted to, woodland.

We then have created two different types of management requirements for those areas back of the mow line for we know that tall grasses will not remain as such without further attention in our climates in Illinois. Two problems are confronted within these areas. One is the encroachment of woody growth. The other is infestation from those plants defined as noxious weeds under Illinois law. These areas then may require periodic application of herbicides or mowing in order to control undesirable vegetation, both of which practices are catastrophic to the establishment of woody cover. In order to separate those areas for maintenance purposes, we changed the type of mow line stake to what we class as a "don't mow, don't spray" marker by adding an orange band at the top of the green post. The spray operator then knows that those areas are planted to seedling plants or have been left to regenerate from the adjoining woodland. In the past, the establishment of woody cover has captured most of our time and imagination since these are the palette of the landscape architect.

The year 1974 saw an emphasis on energy shortage, and in the interest of conservation of both energy and dollars we reduced our mowing once again. This reduction has caused us to abandon the mow line except in a few special cases adjacent to interchanges and urban areas.

Current plans are prepared using a mow line as a base for areas to be planted to seedlings but stakes are not installed except to delineate areas planted to seedlings. In the event our current policy of minimal mowing is liberalized we are prepared to return to the plan which we have developed.

It is only recently that the energy shortage and public opinion has created a climate in which we can begin to explore the full possibilities available in the tall grass prairies. We are interested in utilizing native prairie species of grasses and forbs of those areas ecologically suited for maintenance in tall grasses. It is easy to visualize the aesthetic possibilities that are available in the blossom and color of these prairie species. Some of our early beginnings have been the establishment of monocultures of the bluestems in order to obtain the effect of mass, line, and color during the dormant season. It is our hope that the future will bring better methods, equipment and seed sources to enable us to establish the complete range of prairie vegetation on some of our rights of way. If our efforts are successful, we will then have a complete Vegetation Management Plan. A plan which maximizes our objectives and is a product of the combined inputs for aesthetic appeal, minimal mowing, minimal herbicide application and maximum plant survival. Elements of this plan will be the four vegetation types; steep slope cover, mowed turf, woodland and tall grass prairie.

THE STORY OF PRAIRIE HERITAGE TRAIL IN DANE COUNTY, WISCONSIN

Olive S. Thomson
Route 1
Mt. Horeb, Wisconsin 53572

ABSTRACT

Prairie Heritage Trail is a cooperative effort of the Dane County Highway Commission, the Dane County Natural Beauty Council, and the Dane County Bicentennial Committee as a County Bicentennial Project. The project was planned and implemented in 1975 and in the spring of 1976 opened as a self-guiding auto, biking, and hiking trail. The Dane County Natural Beauty Council persuaded the Highway Commission that roadsides should serve multiple purposes and that a survey of the native vegetation along the right-of-ways should be made. A botanist was hired using the temporary help funds and after completing the survey prepared a management report which was finally adopted as a new policy for the maintenance of the county right-of-ways.

INTRODUCTION

Prairie Heritage Trail, a ten mile stretch of county trunk highway in the prairie area of western Dane County, Wisconsin, is a cooperative effort of the Dane County Bicentennial Committee, the Dane County Highway Commission and the Dane County Natural Beauty Council as a County Bicentennial project. The project was planned and implemented in 1975 and in the spring of 1976 opened as a self-guiding auto, biking, and hiking trail. Attractive brochures with a map, facts of historical and natural history significance, specific information about five areas for stopping places, and notes listing prairie species and other vegetation were charted on a mileage scheme.

METHODS

The fortunate timing of the National Bicentennial Celebration with the current efforts of the Highway Department and the Natural Beauty Council towards the preservation of native vegetation on roadsides gave the impetus which made the project possible. Considerable groundwork had been accomplished before the project was even conceived. The important steps are enumerated as follows:

(1) The Beauty Council stressed to the Highway Commission that they were responsible for a vast acreage of public resource in the right-of-ways which equalled in area the county's park lands and that they should be conscious of the environmental quality of that resource.

(2) The Beauty Council suggested to the Highway Commission that this land be inventoried for possible multi-use and volunteered joint sponsorship of such an inventory.

(3) The element of aesthetics should be considered and the present appearance of most right-of-ways lacked aesthetic qualities.

(4) If a future decision to do less mowing and cutting on right-of-ways were to be made, it would likely be an economy measure and also help save fossil fuels.

(5) A botanist was hired on temporary help funds to survey the 500 miles of county trunk roads and subsequently submit a report with suggestions for future maintenance procedures to the Highway Commission.

(6) The management report was submitted and accepted in the autumn of 1974. It stressed the dominance of plants of European origin on the roadsides, the need for preserving and restoring native species, allowing natural succession to eliminate many weeds, and permitting woody species to grow where there was no concern about safety or vision hazards.

Previous to this time the Dane County Highway Commission had been sufficiently funded for intensive management procedures and followed the common fashion of complete mowing in summer and brush cutting in winter. The use of herbicides had been greatly reduced a few years before.

Dane County Trunk JG had four qualities which made it appropriate to become Prairie Heritage Trail. Several original prairie remnants were adjacent and could serve as a seed source for natural succession if mowing were stopped; steep banks inaccessible to mowing machinery already had aggressive prairie species reestablishing themselves; the road was a pleasant drive for spring flowers and fall color, also lacked traffic hazards; and an excellent site for a prairie restoration project existed at one end of the proposed trail.

RESULTS AND DISCUSSION

In the autumn of 1974 the County Bicentennial Committee was eager for ideas for projects and the suggestion of a joint project was acceptable to both the Highway Commission and the Bicentennial Committee. Implementation of the Prairie Heritage Trail project began by the continued employment of the highway botanist with CETA funds available to the Highway Department. Prairie seeds were gathered in the fall of 1974 and in the spring of 1975 germinated in flats in a county-owned greenhouse. Most of the plants and extra seed were used for the restoration which was a one and one-third acre triangular area at the junction of County Trunks JG, A, and G. The highway department erected red, white, and blue posts and gravelled turn-out areas at each of the five stop places. The Bicentennial Committee provided the expenses for the brochures which were freely distributed in the county. Volunteer workers assisted in the plantings. Previous applications by the county for Federal Bicentennial funds had been rejected but the request for money to purchase a prairie remnant for Prairie Heritage Trail was granted by the National Bicentennial Commission. Other honors received by the county for the project include an EPA (Environmental Protection Award) to the Highway Department and a National County Award to the County. As the bicentennial year draws to an end we are optimistic that Prairie Heritage Trail will be a continuing project and very likely expanded.

Some of the knowledge gained by persons closely involved with this project are summarized here to help others who may attempt similar projects. It engendered a variety of reactions, some positive, some negative. Although the real and first purpose was prairie protection and restoration, it had excellent integrity as a bicentennial project for historical and educational values. To the local community it was very acceptable for reasons of publicity and tourist promotion for the local economy. Persons with high cultural values considered it with high regard and the environmentalists were overjoyed. The general public is looking for a spectacle and Prairie Heritage Trail could in no way provide a spectacle. The highway maintenance crews were generally suspicious and resentful of an intrusion into their domain, and they did not seem interested in being educated into the historical significance of the project. The reactions of adjacent landowners varied from extremely cooperative to uncooperative but perhaps more contact with them might have proved worthwhile. Excellent publicity continued to praise the integrity of the project and provided full support but to too many people a prairie roadside will continue to mean a roadside where the weeds aren't mowed.

New concepts of beauty in which manicuring a roadside isn't necessary, more public education about prairies and natural succession, and the encouragement and popularity of trends to natural landscaping should make it easier to have more Prairie Heritage Trails in other places in the future.

Editor's note: This paper was followed by the Natural Roadsides Slide Set, a 10-minute taped program developed by the Natural Roadsides Committee of the Wisconsin Citizens Environmental Council and produced by the Environmental Resources Unit of the University of Wisconsin Extension. Written and produced by Lynn Entine, photography by Kim Nuzzo, "Natural Roadsides" is available for $22.50 from Bureau of Audio Visual Instruction, P. O. Box 2093, 1327 University Avenue, Madison, WI 53701.

PROPAGATION AND PLANTING OF PRAIRIE FORBS AND GRASSES IN SOUTHERN WISCONSIN

Victoria Nuzzo
Naturalist
Dane County Highway Department
Madison, Wisconsin 53703

ABSTRACT

Prairie is being actively replanted along Dane County Highways as part of the County's Natural Roadsides Management Plan. Twelve thousand seedlings of 48 species of prairie plants were raised in a greenhouse in 1975 and 1976 and subsequently transplanted to the field. Stratification techniques, germination times and transplant survival are discussed for each species.

INTRODUCTION

In March 1975 the Dane County Highway Department adopted a policy of maintaining rights-of-way as natural roadsides. Mowing of the rights-of-way was reduced to the minimum level necessary to maintain safety, and herbicide use was abandoned. In conjunction with this reduction in vegetative removal, a two-phase program of vegetation restoration was initiated. First, all plants other than legally declared noxious weeds or those affecting highway safety were allowed to grow and expand along County Highway rights-of-way. Second, native plants and plant communities were planted to hasten the natural regeneration of the original vegetation.

The major replanting emphasis, both in time and area, has been on prairie restoration. Approximately 1/3 of the 850 ha (2100 acres) of County rights-of-way has some form of existing native vegetation. Of the remaining 566 ha (1400 acres), dominated by weedy, primarily Eurasian plant species, half to three fourths are scheduled to be restored to their original prairie vegetation.

Two methods have been used to hasten this natural process. The first involves a complete removal of the existing plant cover, followed by planting of seeds, and occasionally of plants, of the desired species. This has been termed the plow-and-plant method. The second prairie restoration method, termed the seedling-transplant method, consists of removing all existing vegetation from small areas 30 cm (12 inches) in diameter, and planting a single forb or grass seedling in each bed thus made, without otherwise disturbing the ground cover. As these seedlings mature and reproduce they gradually outcompete the existing non-native vegetation, particularly when aided by a program of controlled burns.

Both restoration methods have distinct advantages and disadvantages. The plow-and-plant method restores an area to prairie in a relatively short time, but requires a high input of seed. This planted area frequently is dominated during the first few years by highly aggressive early-successional Eurasian weeds, and has the appearance of a "weed patch". In contrast, the seedling-transplant method does not disturb the established ground cover, which along Dane County highways tends to be a fairly stable mixture of bluegrass and other native and non-native plants. These roadsides do not appear "weedy" to the general public, and the splashes of color provided by <u>Ratibida pinnata</u>, <u>Rudbeckia hirta</u> and other showy, rapidly-growing prairie forbs help the public to appreciate, rather than denigrate, the prairie restoration program. The seedling-transport method requires far less seed than the plow-and-plant method, but it does require more time and money to raise the seedlings in the greenhouse and transplant them to the field. On a per-acre basis, creating a prairie by the seedling-transplant method requires considerably less time than does the plow-and-plant method: Eighty acres (32.3 ha) of rights-of-way were planted with 6,000 seedlings at a cost of approximately 400 hours, or 5 hours per acre (12 hours per hectare), while 130 hours were expended on a 3 acre (1.2 ha) prairie or 43 hours per acre (10.8 hours per hectare) created by the plow-and-plant method.

Most restoration undertaken in the future by the Dane County Highway Department will involve the seedling-transplant method at a rate to complete our goal in 10 years by this method. In 20 to 30 years these roadsides will significantly resemble the original prairie vegetation in species presence, density and distribution.

METHODS

In 1974 and 1975 seeds of 44 species of prairie forbs and grasses were collected from remnant prairies within 9.6 km (6 miles) of each of several planting sites to ensure ecotype integrity. Seeds were weighed and labeled, then stored in paper bags in a light-proof cabinet.

Several different stratification methods were tested to determine the effects both of different stratification methods on seed collected from the same location and of the same stratification method on seed collected from different locations. Seeds were stratified dry, or in damp vermiculite or damp sand for periods of 6 to 12 weeks, or were not stratified at all.

The seeds were planted in a County-owned greenhouse. Temperatures in this greenhouse varied from 21°C to 32°C (70° to 90°F) during the day, and 4° to 21°C (40° to 70°F) at night. Humidity varied between 40% and 70%. A 35 x 5 feet (10.6 x 1.5 m) bed in this greenhouse was filled to a depth of 4 inches (10 cm) with a 50/50 mixture of silica sand and commercial potting soil (Jiffy Mix* in 1975, Black Magic* in 1976) to create a relatively disease and weed free seedbed. Individual plots were marked off for each species and stratification treatment. The appropriate inoculant was added to each plot assigned to a leguminous species. Milled sphagnum moss was dusted onto the surface of the planted seedbed to reduce the incidence of damp-off. A mist nozzle was used to water the seedbed until the plants were large enough to withstand the force of a gentle hosing.

In 1975 all seeds were planted April 1. The data concerning germination and growth gained from this study determined the 1976 planting dates, which

---

*Mention of brand name does not represent an endorsement of the product.

ranged from January 2 for the slowest growing species to April 15 for the fastest.

Slatted sunshades were placed over the plots of Gentiana andrewsii and G. puberula to prevent rapid drying of the top layer of soil, which would result in death of these delicate seedlings by drying out the diminuitive root systems. The sunshades were removed when the seedlings were 5 months old with roots 1 to 2 inches (2.5 to 5 cm) long.

Seedlings were transplanted into individual pots when the root systems were fairly well developed, which for most species occurred when the seedlings had 3 or 4 leaves. Plastic 3-ounce drinking cups were used in 1975, and 2½ inch (6.3 cm) diameter round peat pots were used in 1976.

Seedlings were transplanted into the field in late May and early June. Signs of readiness included root and shoot growth (roots visible outside of pot, shoots with new leaves) and an ability to survive temporary water stress. These seedlings were planted in clusters of the same or different species, or as scattered individuals, depending on the natural growth form and associates of each species. In plowed fields trowels were used to scoop out a small hole, then the plastic cup, or top of the peat pot, was removed and the seedling placed in the hole slightly below the plant's normal soil line. Soil removed from the hole was used to cover the greenhouse potting soil to prevent excessive drying out of the sandy mixture, and the soil was then tamped down firmly. In established sod shovels were used to dig a hole 6 inches (15.2 cm) deep and 12 inches (30.4 cm) in diameter, and all vegetation was removed from this circle. The seedlings were planted in this exposed soil as just described. No further attention including watering or weed control was given to the seedlings.

RESULTS AND DISCUSSION

The speed of germination varied considerably among the 44 species studied, from a minimum of three days (Aster sericeus and Grindelia squarrosa) to a maximum of 27 days (Gentiana andrewsii) for the first cotyledons to emerge. A few species had no germination at all. The length of the germinating period also varied considerably, with some species, particularly Anemone cylindrica, Anemone patens, Aster ptarmicoides, Aster sericeus, Solidago nemoralis, Solidago rigida and Solidago speciosa producing most of their seedlings within one week from the time of first germination. Other species, such as Amorpha canescens, Baptisia leucophaea, Gentiana andrewsii, Gentiana puberula, Liatris aspera, Liatris cylindracea, Liatris pycnostachya, and Tephrosia virginiana germinated over a period of several weeks. Figures 1 through 8 indicate the germination rates of selected species.

Table 1 lists the different stratification methods given to the various species under study. Some species, such as Bouteloua curtipendula (Fig. 1), were not affected by different stratification methods, and both dry and damp stratified seed germinated and grew at the same rate. Other species were greatly affected, as indicated in Figures 2, 3 and 4. Members of a single genus may have a diversity of germination requirements, such as in Aster (Fig. 5 and 6): Aster sericeus had higher and more rapid germination when stratified in damp vermiculite than when dry stratified; Aster ptarmicoides, on the other hand, had excellent germination when dry stratified, but failed to germinate when damp stratified.

Most species exhibited a preference for dry or damp or no stratification. Of those which preferred damp stratification, only one species was affected by the medium used to retain moisture during the stratification period. Gaura biennis (Fig. 7) germinated rapidly when stratified in damp vermiculite, but seed collected the same day from the same plants and stratified in damp sand germinated extremely slowly. No explanation is proposed for this difference in response.

Different ecotypes of the same species given the same stratification treatments also varied in germination rates (Fig. 8) as did seed collected from the same location but in different years. This variation in germination is to be expected, due to local microclimatic factors of the different collecting sites, or in different years. Despite this variation in germination rates, the general trend of germination of each species tested tended to be similar in 1975 and 1976 (Figs. 9-12).

Seedlings of some species grew exceedingly fast, while others grew quite slowly. This is indicated in Table 1, which lists the age in weeks when seedlings of each species were transplanted from the seedbed to individual pots and later into the field. Three-ounce plastic cups with holes punched in the bottoms were used in 1975 at a cost of 1/2 cent each. When transplanted to the field, the plastic cups were left on the ground to mark the location of each plant until all the seedlings were planted. The cups were then collected and reused. The 5,000 plastic drinking cups on the ground gave an appearance of litter, and they were difficult to collect because the aggressive Eurasian weeds rapidly overgrew and hid the cups. In response to these problems, 2-1/2 inch (6.3 cm) round peat pots were used in 1976, at a cost of 1.7 cents each. Some of the peat pots deteriorated after several months in the greenhouse, but the majority remained intact. When transplanted to the field, the part of the peat pot above the inner soil line was removed, to prevent the thin layer of pressed peat from acting as a moisture barrier. Peat pots will be used in future greenhouse work in preference to non-biodegradable plastic cups.

Seedlings were transplanted from the seedbed into individual pots at a minimum age of three weeks (Bouteloua curtipendula and Gaura biennis) and at a maximum age of 6 months (Gentiana puberula). The age to transplant was determined primarily by the size and vigor of the root system, and secondarily by the size and vigor of the shoot.

Some species exhibited little or no negative response to transplanting and grew rapidly within a few days of being placed in individual pots. In general, these species (Anemone cylindrica, Andropogon gerardi, Andropogon scoparius, Aster ptarmicoides, Aster sericeus, Solidago nemoralis, Solidago rigida and Solidago speciosa) had high germination rates and were extremely crowded, hence stunted, in the seedbed. Once removed from the competition of the seedbed these plants grew rapidly and strongly. Some species, such as Aster novae-angliae, Eupatorium perfoliatum, Gaura biennis, Grindelia squarrosa, Helianthus laetiflorus and Monarda fistulosa, wilted severely immediately after

Table 1: Propagation Data for 44 Species of Prairie Plants

Species	Type Stratification	Days to First Germination	Days to Peak Germination	Approx. No. of Seedlings per Ounce Cleaned Seed	Age in Weeks When Transplanted to Pot	to Field	Survival in Field	Years Till First Flower	Years Till Most Flowers
Amorpha canescens	8[a] dry	--	--	--	--	--	--	--	--
	10 damp	6	20	1,000	6	10	poor	NA	NA
Andropogon gerardi	10 dry	5	20	1,000	5	8	good	1	NA
Andropogon scoparius	10 dry	5	20	1,000	6	8	NA	NA	NA
Anemone cylindrica	none	15	24	1,500	6	10	fair	2	2
	10 damp	14	28	1,000	6	10	fair	2	2
Anemone patens	16 dry	9	17	700	6	10	poor	NA	NA
Aster ericoides	none	8	15	75	5	8	exc.	1	2
	8 dry	27	NA	2	NA	NA	NA	NA	NA
	8 damp	8	27	75	8	22	NA	NA	NA
Aster laevis	none	7	20	100	5	10	exc.	1	2
Aster novae-angliae	16 dry	7	12	200	4	8	exc.	1	2
Aster ptarmicoides	10 dry	6	14	1,500	5	8	exc.	1	2
	10 damp	--	--	--	--	--	--	--	--
Aster sericeus	10 dry	3	11	300	4	8	exc.	1	2
	10 damp	3	10	700	4	8	exc.	1	2
Baptisia leucophaea	6[b] damp	5	10	500	6	22	NA	NA	NA
Bouteloua curtipendula	10 dry	5	12	1,700	3	8	good	1	NA
	10 damp	5	12	1,700	3	8	good	1	NA
Coreopsis palmata	8 damp	4	14	300	4	8	fair	2	NA
Desmodium canadense	none	14	28	30	6	10	poor	NA	NA
Desmodium illinoense	none	7	15	80	6	10	poor	NA	NA
Eupatorium perfoliatum	16 dry	8	14	150	5	8	exc.	1	2
Galium boreale	none	17	28	high	7	14	NA	NA	NA
Gaura biennis	10 damp sand	9	75	25	12	22	exc.	2	2
	10 damp verm.	6	13	140	3	8	exc.	2	2
Gentiana andrewsii	8 dry	--	--	--	--	--	--	--	--
	8 damp	27	45	high	20	36	NA	NA	NA
Gentiana puberula	12 dry	--	--	--	--	--	--	--	--
	8 damp	18	40	high	24	36	NA	NA	NA
Grindelia squarrosa	10 damp	3	14	1,700	6	10	exc.	1	2
Helianthus laetiflorus	10 dry	15	49	400	8	8	NA	NA	NA
Heuchera richardsonii	16 dry	15	22	high	10	26	NA	NA	NA
Koeleria cristata	10 dry	10	NA	low	6	10	NA	NA	NA
	10 damp	7	19	low	6	10	NA	NA	NA
Kuhnia eupatorioides	8 dry	5	12	300	6	22	NA	NA	NA
Lespedeza capitata	10 dry	7	14	250	5	10	poor	NA	NA
	10 damp	7	22	50	5	10	poor	NA	NA
Liatris aspera	10 dry	6	45	500	12	22	poor	NA	NA
Liatris cylindracea	10 dry	8	45	400	14	22	poor	NA	NA
Liatris pycnostachya	8 dry	14	30	800	12	20	1	NA	NA
Monarda fistulosa	none	6	14	high	5	8	exc.	2	NA
	16 dry	7	14	high	5	8	exc.	2	2

Table 1 (continued)

Species	Type Stratification	Days to First Germination	Days to Peak Germination	Approx. No. of Seedlings per Ounce Cleaned Seed	Age in Weeks When Transplanted to Pot	Age in Weeks When Transplanted to Field	Survival in Field	Years Till First Flower	Years Till Most Flowers
Petalostemum purpureum	10 dry	5	12	110	5	10	fair	2	2
	10 damp	5	14	50	5	10	fair	2	2
Pycnanthemum virginianum	16 dry	13	20	low	6	8	fair	2	2
Ratibida pinnata	10 dry	5	13	400	6	10	exc.	2	2
	10 damp	5	13	300	6	10	exc.	2	2
Rudbeckia hirta	16 dry	6	14	1,000	6	8	exc.	1	2
Rudbeckia laciniata	8 dry	6	20	200	4	6	good	NA	NA
Solidago graminifolia	16 dry	8	14	1,000	6	8	fair	NA	NA
Solidago nemoralis	none	6	10	1,000	5	10	exc.	2	2
Solidago rigida	10 dry	6	14	150	6	10	exc.	2	2
Solidago speciosa	10 dry	5	13	500	6	9	poor	NA	NA
Sorghastrum nutans	10 dry	8	19	300	6	10	NA	NA	NA
	8 damp	8	20	1,500	8	22	NA	NA	NA
Sporobolus heterolepis	10 dry	7	25	2,000	7	10	NA	NA	NA
Tephrosia virginiana	10[b] damp	5	40	50	5	10	poor	NA	NA
Thalictrum dasycarpum	8 damp	12	20	800	10	22	NA	NA	NA

[a] Numbers in this column indicate the number of weeks stratified

[b] Seeds were also scarified

being transplanted from the seedbed, but recovered quickly and were ready to transplant to the field within 2 to 3 weeks. Grindelia squarrosa and Gaura biennis in particular needed four weeks from the time of seedling planting to time of transplanting to the field. If the seedlings were too large when transplanted they would wilt and die before the root systems were able to obtain sufficient moisture. A few of the species in this study had distinct taproots, such as Kuhnia eupatorioides, Helianthus laetiflorus and Tephrosia virginiana. It was necessary to transplant these seedlings before the taproots grew too large and deformed in the cramped space available.

Some species needed a long growth period in the seedbed before they could survive transplanting to individual pots. The small brittle taproots of young Liatris seedlings tended to snap when transplanted. Only after three months, when a corm 1/8 inch (0.3 cm) in diameter was formed, could the seedlings survive transplanting. Liatris seedlings 4 to 5 months old had 2 to 8 leaves and larger corms up to 1/2 inch (1.2 cm) in diameter, and transplanted very easily. Beyond 5 months no significant increase in transplant survival was noted for the three Liatris species studied. Gentiana andrewsii, Gentiana puberula and Heuchera richardsonii also needed 3 to 5 months in the seedbed before they were large and sturdy enough to transplant easily.

Many of the seedlings raised in this study were planted on an extremely droughty limestone slope in thin soil. In order to prevent immediate die-off due to the high temperatures and the low available water conditions existing in the planting site, a watering regimen was initiated in the greenhouse to adapt the seedlings to periodic water stress. This program consisted of heavily watering the seedlings, then not watering for 1 to 3 days, until the plants were fairly to severely wilted. During this time the temperature inside the greenhouse averaged 90°F (32°C). Many of the seedlings adapted to this drought-or-flood watering regimen and were able to tolerate extended periods of drought both in the greenhouse and in the field.

Most seedlings had a remarkable ability to resprout. Desmodium seedlings, with the tops dried and dead from fertilizer burn, resprouted after several weeks forming large healthy shoots. Several times a number of the seedlings in the greenhouse appeared dead due to water loss. When watered heavily almost all sent up new shoots within a few weeks. These species included Amorpha canescens, Anemone patens, Aster sericeus, Baptisia leucophaea, Desmodium canadense, Liatris aspera, Liatris cylindracea, Liatris pycnostachya, Petalostemum purpureum and Sporobolus heterolepis. A few species were unable to recover from these drought periods: Anemone cylindrica, Ratibida pinnata, Solidago speciosa and Thalictrum dasycarpum.

The seedlings were planted in the field in late May and early June. Adequate rainfall was received in 1975 for the seedlings to grow without water stress, but very little rain fell in 1976 (1.48 inches on May 15 and 16; .40 inch on June 13; .88 inch on July 28; and .43 inch on July 30) and seedlings transplanted to the field in this year suffered greatly from drought. Many of the species which did not survive transplanting in 1976 would probably survive in a year of normal rainfall. The survival ratings given each species in Table 2 are based on the response of each species to normal weather conditions.

Transplant survival varied greatly among the different species, not withstanding the effects of weather. Some plants, such as Tephrosia virginiana, which transplanted with no problems from the seedbed to the pot, had difficulty surviving in the field. Others exhibited remarkable tenacity. Aster ericoides, Aster laevis, Aster novae-angliae, Aster ptarmicoides, Aster sericeus, Eupatorium perfoliatum, Gaura biennis, Grindelia squarrosa, Kuhnia eupatorioides, Ratibida pinnata, Monarda fistulosa, Rudbeckia hirta, Solidago nemoralis and Solidago rigida displayed a high ability to survive and grow in the adverse growing conditions in which they were planted. Other species, particularly Amorpha canescens, Anemone cylindrica, Anemone patens, Lespedeza capitata, Liatris aspera, Liatris cylindracea, Solidago graminifolia and Tephrosia virginiana were unable to survive these harsh conditions, although they did quite well in the greenhouse. In less harsh conditions, Anemone cylindrica, Lespedeza capitata and Solidago graminifolia were able to grow both strongly and vigorously. Between these two extremes are a few species--Coreopsis palmata, Desmodium canadense, Desmodium illioense, Petalostemum purpureum and Pycnanthemum virginianum--which had difficulty surviving in the field, but once established were very strong and healthy.

Individual seedlings of Galium boreale transplanted easily to peat pots but had poor survival in the field. However, dense sods 6 inches (15.2 cm) square and 2 inches (5 cm) deep of Galium boreale seedlings, taken directly from the seedbed and transplanted to the field, survived and grew dramatically despite 2 weeks without rain. After 6 weeks of drought these sods also died. During a year of normal rainfall these sods would probably have excellent survival, would vegetatively expand at a faster rate, and require less time to transplant than the individually potted seedlings. Several hundred 1-inch to 4-inch (2.5 to 10 cm) square sods of a variety of prairie plant seedlings will be plugged into a mesic prairie planting site in late September, 1976. Success is predicted for all the grasses, and for the larger forbs, including Liatris species with corms 1/2 inch (1.2 cm) in diameter or larger, but it appears unlikely that tiny Aster or Solidago seedlings will survive in the field without first being transplanted into individual pots.

The ability of seedlings to survive in the field can be broken down into three categories: (1) Those which transplanted easily to the field and grew rapidly are:

> Andropogon gerardi, Aster ericoides, Aster laevis, Aster novae-angliae, Aster ptarmicoides, Aster sericeus, Bouteloua curtipendula, Eupatorium perfoliatum, Gaura biennis, Grindelia squarrosa, Kuhnia eupatorioides, Monarda fistulosa, Ratibida pinnata, Rudbeckia hirta, Solidago nemoralis, Solidago rigida.

(2) Those which died in the field despite healthy growth in the greenhouse are:

> Amorpha canescens, Anemone patens, Liatris aspera, Liatris cylindracea, Solidago speciosa, Tephrosia virginiana.

(3) Those which had difficulty surviving in the field, but once established became very strong and healthy are:

> Anemone cylindrica, Coreopsis palmata, Desmodium canadense, Desmodium illinoense, Lespedeza capitata, Petalostemum purpureum, Pycnanthemum virginianum, Solidago graminifolia.

During a year of normal rainfall many more seedlings would be expected to survive (Table 2).

Several species were too small or delicate to survive in the field their first year of growth. These species (Anemone patens, Amorpha canescens, Baptisia leucophaea, Gentiana andrewsii, Gentiana puberula, Liatris aspera, Liatris cylindracea, and possibly Liatris pycnostachya and Petalostemum purpureum) would do better if transplanted from the greenhouse (or seeded directly) into a holding bed which could be watered and weeded as necessary. The following spring these yearling plants would be large and sturdy enough to survive transplanting to the field.

In very dry sites the presence of vigorous, rapidly growing weeds actually benefitted the young prairie plants by providing shade, cooler temperatures and increased humidity. Monarda fistulosa and Ratibida pinnata seedlings sheltered by a dense growth of Melilotus officinalis, were 2 to 4 times as large as exposed seedlings in the year following transplanting. Seedlings planted in mesic sites by the seedling-transplant method (in somewhat sunken, weed-free circles 12 inches (30 cm) in diameter) likewise were little affected by the presence of weedy species.

Nine species of plants bloomed the same year they were transplanted to the field. Bouteloua curtipendula even produced spikelets in the greenhouse when three months old, both in 1975 and 1976. Aster ericoides, Aster novae-angliae, Grindelia squarrosa and Rudbeckia hirta produced a significant display of color during their first year. Andropogon gerardi, Aster laevis, Aster sericeus, and Bouteloua curtipendula produced only a few scattered flowers. The year following transplanting (the second year) 19 species produced flowers. Nearly all plants of Anemone cylindrica, Aster ericoides, Aster laevis, Aster novae-angliae, Aster ptarmicoides, Aster sericeus, Eupatorium perfoliatum, Gaura biennis, Grindelia squarrosa, Monarda fistulosa, Petalostemum purpureum, Pycnanthemum virginianum, Ratibida pinnata, Rudbeckia hirta, Solidago nemoralis and Solidago rigida bloomed in this year. Many, but not most, plants of Andropogon gerardi, Bouteloua curtipendula and Coreopsis palmata also produced flowers in their second year. It is expected that by the third summer most, if not all, of the transplanted seedlings will produce flowers.

Vegetative reproduction, the "bunching" effect typical of prairie plants was evident in some species while still in the greenhouse. Andropogon gerardi, Andropogon scoparius, Bouteloua curtipendula,

Table 2: A comparison of three propagation methods for 44 species of prairie forbs and grasses. Each method is rated poor, fair, good or excellent according to the response of each plant species assuming normal weather.

Species	Propagation Method: Direct Seeding	Seedling Transplant	Year-Old Plant
Amorpha canescens	Poor	Poor	Good
Andropogon gerardi	Good	Good	Good
Andropogon scoparius	Good	Good	Good
Anemone cylindrica	Poor	Poor	Good
Anemone patens	Poor	Poor	Good
Aster ericoides	Poor	Excellent	Excellent
Aster laevis	Good	Excellent	Good
Aster novae-angliae	Good	Excellent	Excellent
Aster ptarmicoides	Fair	Excellent	Good
Aster sericeus	Fair	Excellent	Good
Baptisia leucophaea	Fair	Poor	Fair
Bouteloua curtipendula	Good	Excellent	Good
Coreopsis palmata	Fair	Good	Excellent
Desmodium canadense	Fair	Poor	Fair
Desmodium illinoense	Fair	Poor	Fair
Eupatorium perfoliatum	Good	Excellent	Good
Galium boreale	Fair	Excellent (as sods)	Excellent
Gaura biennis	Good	Excellent	Fair
Gentiana andrewsii	Poor	Poor	Good
Gentiana puberula	Poor	Poor	Fair
Grindelia squarrosa	Excellent	Excellent	Excellent
Helianthus laetiflorus	Good	Good	Fair
Heuchera richardsonii	Poor	Fair	Good
Koeleria cristata	Poor	Poor	Good
Kuhnia eupatorioides	Excellent	Excellent	Good
Lespedeza capitata	Fair	Poor	Good
Liatris aspera	Good	Good	Good
Liatris cylindracea	Fair	Poor	Good
Liatris pycnostachya	Good	Poor	Good
Monarda fistulosa	Excellent	Excellent	Excellent
Petalostemum purpureum	Good	Good	Excellent
Pycnanthemum virginianum	Fair	Fair	Good
Ratibida pinnata	Good	Excellent	Good
Rudbeckia hirta	Excellent	Excellent	Excellent
Rudbeckia laciniata	Good	Good	Fair
Solidago graminifolia	Poor	Good	Good
Solidago nemoralis	Good	Excellent	Good
Solidago rigida	Fair	Excellent	Good
Solidago speciosa	Good	Good	Good
Sorghastrum nutans	Fair	Good	Fair
Sporobolus heterolepis	Poor	Good	Good
Stipa spartea	Poor	Fair	Fair
Tephrosia virginiana	Fair	Fair	Fair
Thalictrum dasycarpum	Good	Excellent	Good

Coreopsis palmata, Galium boreale, Koeleria cristata, Monarda fistulosa and Sporobolus heterolepis all developed distinct "bunch" forms before being transplanted to the field. By the end of the first year in the field Rudbeckia hirta and Ratibida pinnata also formed bunches. In the second year almost every plant of 22 species had 2 or more shoots. Besides the species just mentioned Aster ericoides, Aster laevis, Aster novae-angliae, Aster ptarmicoides, Aster sericeus, Eupatorium perfoliatum, Gaura biennis, Grindelia squarrosa, Petalostemum purpureum, Pycnanthemum virginianum, Solidago nemoralis and Solidago rigida formed distinct bunches during their second year of growth.

During two years of propagating prairie plants and undertaking the initial steps in recreating prairies, much information has been gained concerning effective propagation methods for different species.

BIBLIOGRAPHY OF PRAIRIE PROPAGATION

Blake, A. K. 1935. Viability and germination of seed and early life histories of prairie plants. Ecol. Monographs 5:405-460.

Cull, M. I. 1978. Establishing prairie vegetation along highways in the Peoria area (these proceedings).

Egler, F. E. 1954. Vegetation management for right of ways and roadsides. Smithsonian Institution Report for 1953:299-322.

Greene, H. C. 1949. Notes on revegetation of a Wisconsin sandy oak opening, 1943-1949. Unpublished manuscript, Univ. of Wis. Arboretum, Madison, Wis.

Greene, H. C. and J. T. Curtis. 1950. Germination studies of Wisconsin prairie plants. Amer. Midl. Nat. 43:186-194.

Greene, H. C. and J. T. Curtis. 1953. The establishment of prairie in the University of Wisconsin Arboretum. Wild Flower 29:77-88.

Landers, R. Q. 1970. The use of prairie forbs and grasses in Iowa roadside and park landscapes. Proc. Second Midwest Prairie Conf. 180-183.

Mayer, A. and A. Poljakoff-Mayber. 1963. The germination of seeds. New York, Macmillan. 236 pp.

Ode, A. H. 1970. A rationale for the use of prairie species in roadside vegetation management. Proc. Second Midwest Prairie Conf. 174-179.

Rock, H. 1971. Prairie propagation handbook, Boerner Botanical Gardens, Hales Corners, Wis. 60 pp.

Schramm, P. 1970. Ed. Proc. symposium on prairie and prairie restoration. Knox College Biol. Field Sta. Pub. No. 3. Galesburg, Ill.

Schramm, P. 1978. Do's and don't's of prairie restoration (these proceedings).

Schulenberg, R. F. 1970. Summary of Morton Arboretum prairie restoration work, 1963-1968. Proc. Symposium on Prairie and Prairie Restoration. Knox College Biol. Field Sta. Spec. Pub. No. 3. Galesburg, Ill. 45-46.

Threfall, A. 1970. Studies on germination of Dodecatheon meadia. Proc. Second Midwest Prairie Conf. 162-165.

Whitford, P. B. 1972. Native plants as roadside vegetation. Newsletter of the Bot. Club of Wisc. 4:14-22.

Zimmerman, J. H. 1970. Propagation of spring prairie plants. Proc. Second Midwest Prairie Conf. 153-161.

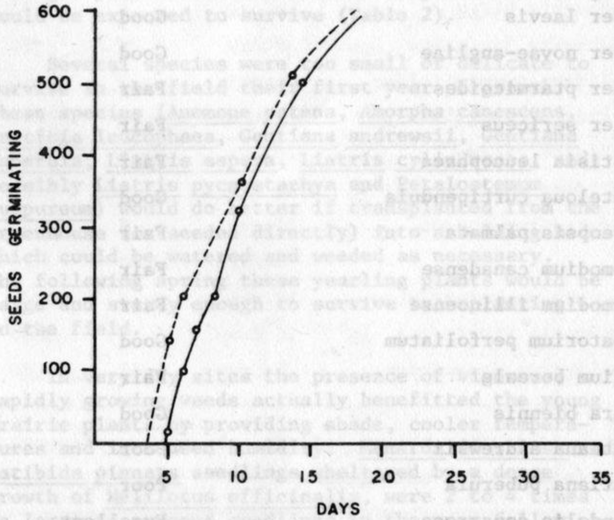


Fig. 1. Bouteloua curtipendula. A comparison of the germination rates of ½ ounce dry-stratified seed (solid line) and ½ ounce damp-stratified seed (dotted line).

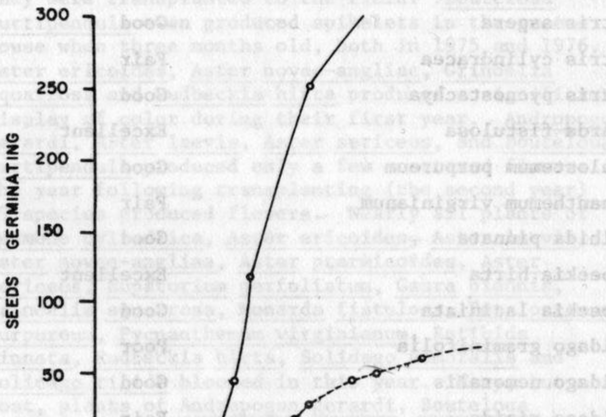


Fig. 2. Lespedeza capitata. A comparison of the germination rates of 1 ounce dry-stratified seed (solid line) and 1 ounce damp-stratified seed (dotted line).

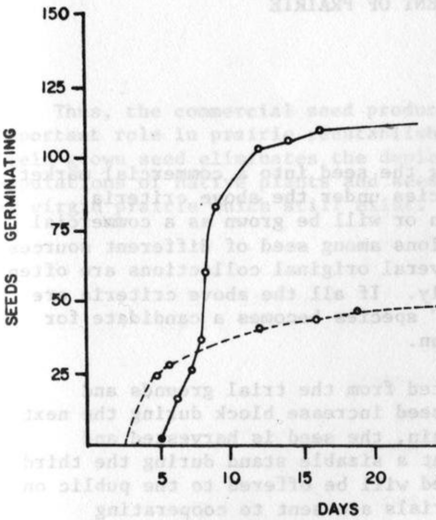


Fig. 3. Petalostemum purpureum. A comparison of the germination rates of 1 ounce dry-stratified seed (solid line) and 1 ounce damp-stratified seed (dotted line).

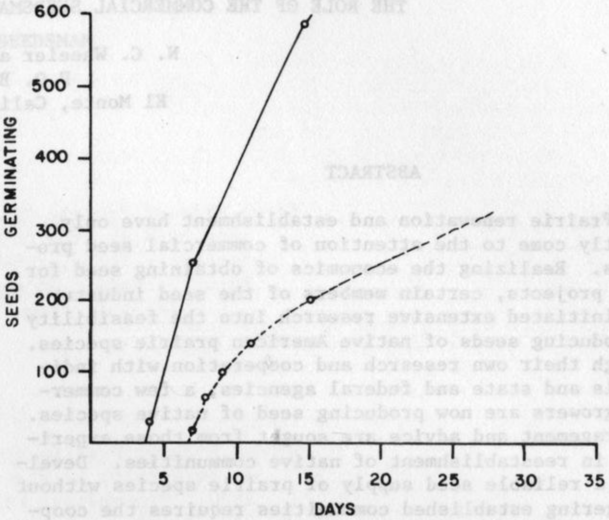


Fig. 6. Aster sericeus. A comparison of the germination rates of 1 ounce dry-stratified seed (solid line) and 1 ounce damp-stratified seed (dotted line).

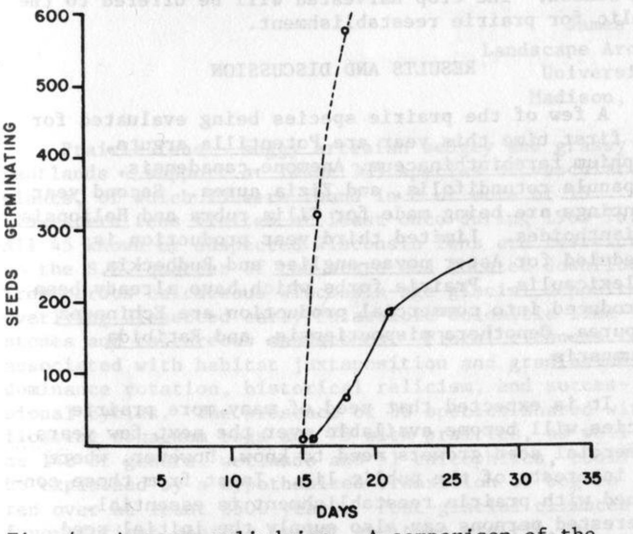


Fig. 4. Anemone cylindrica. A comparison of the germination rates of 1 ounce damp-stratified seed (dotted line) and 1 ounce non-stratified seed (solid line).

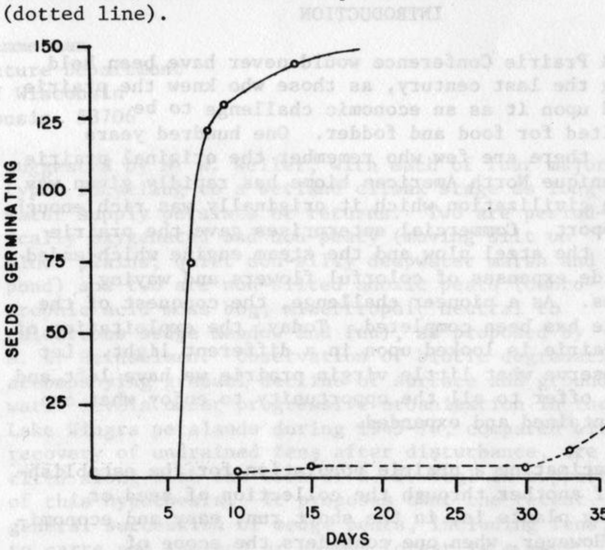


Fig. 7. Gaura biennis. A comparison of the germination rates of 1 ounce of seed stratified in damp vermiculite (solid line) and 1 ounce stratified in damp sand (dotted line).

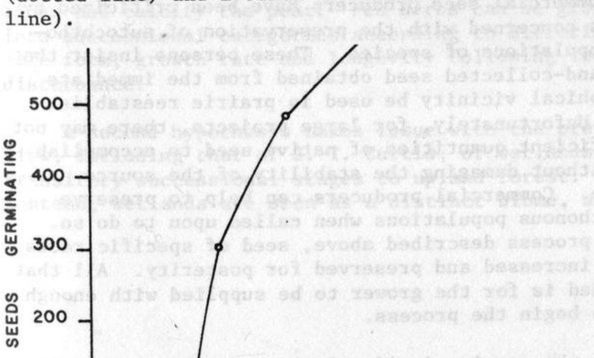


Fig. 5. Aster ptarmicoides. A comparison of the germination rates of 1 ounce dry-stratified seed (solid line) and 1 ounce damp-stratified seed (dotted line).

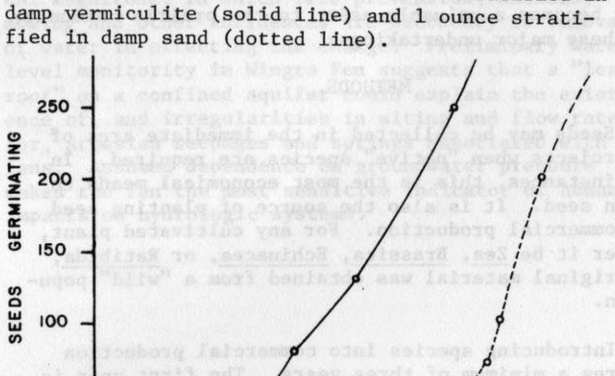


Fig. 8. Liatris aspera. A comparison of the germination rates of 2 ounces of seed from each of 2 different ecotypes.

THE ROLE OF THE COMMERCIAL SEEDSMAN IN THE REESTABLISHMENT OF PRAIRIE

N. C. Wheeler and M. F. Tessene
P.O. Box 5904
El Monte, California 91734

ABSTRACT

Prairie renovation and establishment have only recently come to the attention of commercial seed producers. Realizing the economics of obtaining seed for major projects, certain members of the seed industry have initiated extensive research into the feasibility of producing seeds of native American prairie species. Through their own research and cooperation with individuals and state and federal agencies, a few commercial growers are now producing seed of native species. Encouragement and advice are sought from those experienced in reestablishment of native communities. Developing a reliable seed supply of prairie species without endangering established communities requires the cooperation of those having the knowledge of native prairie with those who supply the seed.

INTRODUCTION

A Prairie Conference would never have been held during the last century, as those who knew the prairie looked upon it as an economic challenge to be exploited for food and fodder. One hundred years later, there are few who remember the original prairie. This unique North American biome has rapidly given way to the civilization which it originally was rich enough to support. Commercial enterprises gave the prairie farmer the steel plow and the steam engine which ended the wide expanses of colorful flowers and waving grasses. As a pioneer challenge, the conquest of the prairie has been completed. Today, the exploitation of the prairie is looked upon in a different light. Let us preserve what little virgin prairie we have left and let us offer to all the opportunity to enjoy what can be maintained and expanded.

Decimating a prairie population for the establishment of another through the collection of seed or removing plants is, in the short run, easy and economical. However, when one considers the scope of potential prairie reestablishment projects, such practices become self-defeating. The commercial supplier becomes a valuable asset to the prairie community for these major undertakings.

METHODS

Seeds may be collected in the immediate area of any projects when "native" species are required. In many instances, this is the most economical means to obtain seed. It is also the source of planting seed for commercial production. For any cultivated plant, whether it be Zea, Brassica, Echinacea, or Ratibida, the original material was obtained from a "wild" population.

Introducing species into commercial production requires a minimum of three years. The first year is the most difficult and critical. The apparently simple process of obtaining seed of the requisite species frequently ends in frustration and necessitates a privately sponsored collecting expedition by a member of the commercial firm. Once the seed is obtained, it is germinated and grown under many conditions. To be judged economically, each species is evaluated under many criteria, including but not limited to ease of germination, growth, adaptation to growing area, feasibility of mechanical harvest, and, of course, the potential of selling the seed into a commercial market. Evaluation of a species under the above criteria determines if it can or will be grown as a commercial crop. Minor variations among seed of different sources are noted, since several original collections are often judged simultaneously. If all the above criteria are favorable, the "new" species becomes a candidate for commercial production.

Seed is harvested from the trial grounds and planted in a stock seed increase block during the next growing season. Again, the seed is harvested and enough saved to plant a sizable stand during the third year. Any extra seed will be offered to the public on a limited basis. Trials are sent to cooperating agencies throughout the country for their evaluation.

Full production will begin during the third growing season. The crop harvested will be offered to the public for prairie reestablishment.

RESULTS AND DISCUSSION

A few of the prairie species being evaluated for the first time this year are *Potentilla arguta*, *Silphium terebinthinaceum*, *Anemone canadensis*, *Campanula rotundifolia*, and *Zizia aurea*. Second year plantings are being made for *Gilia rubra* and *Heliopsis helianthoides*. Limited third year production is scheduled for *Aster novae-angliae* and *Rudbeckia amplexicaulis*. Prairie forbs which have already been introduced into commercial production are *Echinacea purpurea*, *Oenothera missouriensis*, and *Ratibida columnaris*.

It is expected that seed of many more prairie species will become available over the next few years. Commercial seed growers need to know, however, where the interests of the public lie. Input from those concerned with prairie reestablishment is essential. Interested persons can also supply the initial seed for evaluation.

Commercial seed producers have been criticized by persons concerned with the preservation of autochthonous populations of species. These persons insist that only hand-collected seed obtained from the immediate geographical vicinity be used in prairie reestablishment. Unfortunately, for large projects, there may not be sufficient quantities of native seed to accomplish this without damaging the stability of the source prairie. Commercial producers can help to preserve autochthonous populations when called upon to do so. By the process described above, seed of specific races can be increased and preserved for posterity. All that is needed is for the grower to be supplied with enough seed to begin the process.

If the species is identical or similar to one that is already being commercially grown, the first two years in the process can sometimes be eliminated. For example, *Rudbeckia hirta* has been grown by seedsmen for a number of years. If an individual or organization needing large quantities of a particular race of *R. hirta* can supply the grower with sufficient planting seed, usually about four pounds, a crop can be harvested the first season. All seed returned will be as genetically identical to that of the original seed as possible.

Thus, the commercial seed producer does play an important role in prairie reestablishment. The use of field-grown seed eliminates the depletion of native populations of native plants and seeds in the remnants of virgin prairie which still exist.

NOTES ON WISCONSIN PRAIRIE FENS - CHARACTERISTICS AND RELATIONSHIPS

James H. Zimmerman
Landscape Architecture Department
University of Wisconsin
Madison, Wisconsin 53706

Prairie fens - soggy artesian sedgey and grassy peatlands - support at least 333 species of vascular plants, of which 73 were found in 8 or more of 15 midwestern fens visited at least once during 1965-76. All 45 known or suspected Wisconsin fens are restricted to the S.E. quarter of the state and located downflow from porous calcareous Wisconsin-age glacial deposits overlying dissected early Palaeozoic dolomitic limestones and calcareous sandstones. Floral richness is associated with habitat juxtaposition and gradiation, dominance rotation, historical relicism, and successional cycles. The presence of 30 species shared with floating sphagnum bogs and 75 with prairies, as well as 148 of general wetlands and 51 calcophiles, could be explained by a hypothesized transition of bog to fen over at least 8500 years. Post-glacial climates favored first conifer forest and then prairie, as suggested by a few fossils and the presumption of steady ground water supply to maintain relic populations and calcify the peat. Fen herbs can be grouped into successional categories according to differing life form, growth rate and longevity following local disturbance.

A second hypothesis takes issue with the prevalent view, including that of J. T. Curtis, of wetlands as transitory successional stages to upland forest. Instead, wetlands are seen as a distinct biome, as suggested by M. W. Weller, with each of four major types recycling to a wetland climax stage as long as water supply persists or returns. Two are periodically oxygenated and non-peaty (moving silt on flood plains; quiet non-silty deepwater marsh and pond) and two are non-silted anoxic peats (ombrotrophic acid moss bog; minertrophic neutral to calcareous sedge meadow and fen), as proposed by M. L. Heinselman. Observation of biotic degradation accompanying gradual decline of surface and ground water levels under progressive urbanization in the Lake Wingra petalands during 1945-76, compared with recovery of undrained fens after disturbance, are cited along with the work of R. J. Vogl in support of this hypothesis. It proposes that the recent general succession of sedge peats, including fens, to carrs and lowland or upland forest is a man-caused change of geological rather than mere biological magnitude, in which fire prevention, animals, mowing and other influences are secondary to removal of water in effecting the change. Preliminary water-level monitority in Wingra Fen suggests that a "leaky roof" on a confined aquifer could explain the existence of, and irregularities in siting and flow rates for, artesian seepages and springs associated with fens. Assumed dependence on groundwater pressure makes the fen the most sensitive indicator of human impacts on hydrologic systems.

<u>First</u> <u>Midwest</u> <u>Prairie</u> <u>Conference</u> <u>Proceedings</u>. Conference held at Knox College, Galesburg, Illinois, September 14-15, 1968. Proceedings edited by Peter Schramm. 66 pp.

Obtainable from: Peter Schramm
Knox College
Galesburg, IL 61401
Price: $4.75 postpaid

<u>Second</u> <u>Midwest</u> <u>Prairie</u> <u>Conference</u> <u>Proceedings</u>. Held at University of Wisconsin, September 18-20, 1970. Proceedings edited by James H. Zimmerman. 242 pp.

Obtainable from: James H. Zimmerman
University of Wisconsin Arboretum
1207 Seminole Highway
Madison, WI 53711
Price: $6.00 postpaid

<u>Third</u> <u>Midwest</u> <u>Prairie</u> <u>Conference</u> <u>Proceedings</u>. Held at Kansas State University, September 22-23, 1972. Proceedings edited by Lloyd C. Hulbert. 91 pp.

Obtainable from: Division of Biology
Kansas State University
Manhattan, KS 66506
Price: $6.00 postpaid

<u>Fourth</u> <u>Midwest</u> <u>Prairie</u> <u>Conference</u> <u>Proceedings</u>. Held at University of North Dakota, August 19-22, 1974. Proceedings edited by Mohan K. Wali. 433 pp.

Obtainable from: Univeristy of North Dakota Press
P.O. Box 8006, University Station
Grand Forks, ND 58202
Price: $10.00 postpaid

Also published: <u>Supplement</u> <u>to</u> <u>Prairie</u>: <u>A</u> <u>Multiple</u> <u>View</u>. 466 pp. (Native grassland ecosystems east of the Rocky Mountains in North America: a preliminary bibliography)

Obtainable from University of North Dakota Press, $7.00 postpaid

HISTORY, POLITICS AND EDUCATION

This diverse section may fit the miscellaneous category very well; however, it contains papers which attempt to tie us all together. The historical is emphasized by Smith in a unique personal account of prairie influence and by Twedt and Wolfe in the Nebraska sandhills. Prairie preservation in Iowa is outlined by Roosa, in Ohio by Ramey and Troutman, and proposed for a national park by Page.

The politics of saving a prairie in the midst of industry is described for the Hoosier Prairie by Herlocker. Testing a local weed law restricting growth of native plants as a lawn is described by Otto. And Yates discusses the inadequate politics of Aldo Leopold.

The paper by Peart demonstrates the program in Canada for public education on natural resources. Platt describes his successful use of the prairie as an outdoor classroom. And Drake discusses the value of understanding the functions of the prairie with potential application for agriculture.

"MYSTIQUE" OF THE PRAIRIE

Daryl Smith
Biology Department
University of Northern Iowa
Cedar Falls, Iowa 50613

As I have visited, studied and searched for prairies during the past several years, I have attempted to ascertain what it is about prairies that holds such a fascination for me and others. I am becoming increasingly convinced that some of the answers have to be sought beyond the tangible realm of our senses. Jim and Alice Wilson (1967) maintain, "There is a mysterious something about the native grasses--a power, a spirit, a mystique--that both stirs the soul and quiets it."

When the European settlers first entered mid-continent North America, they were confronted with a vast vista of grassland. This was a different landscape, a new experience. Their first major introduction to the prairie occurred on the Grand Prairie of Illinois, although sneak previews of the tall-grass had begun in Ohio and Indiana. The tall-grass prairie seemed endless as it stretched westward to the Missouri River and beyond. Catching the southwest corner of Wisconsin, it covered the western parts of Missouri and Minnesota and almost all of Iowa, extended into the eastern Dakotas, deep into Nebraska, down into Kansas, Oklahoma and Texas and north into Manitoba. Mixed grass and short grass prairie occupied the area west to the Rocky Mountains.

An early Iowa settler could walk out of a forest on the Mississippi floodplain, climb a bluff harboring familiar maples and basswoods, and stand among the oaks and hickorys at the top to behold, to the west as far as the eye could see, a vast green sea of waving grass with only an occasional stand of timber. As Audrey Hirsch (1975) so aptly put it, "The prairie is distinctive because of its grass, but the prairie is not only grass; it is forest edges; it is valleys; it is vast savannas with clumps of burr oak trees; it is rocky outcrops; it is birds and animals; it is bright flowers and seed heads that rattle and blow in the wind." Yet the prairie is more, it is sun and wind and sky with horizons that never end.

The prairie is gone now, all that remain are a few scattered relics in old settler cemeteries, roadsides and railroad right-of-ways. The prairie may be gone but it is not forgotten. Stop and reflect for a moment, what images do the word "prairie" bring to your mind. Whenever people discuss prairies an undercurrent of excitement seems to flow through the group. What is it about an ecosystem of the past that generates such electricity? Few people have actually spent time on the prairie, so it is not likely that they are stimulated by direct experience. Perhaps much of the interest is nostalgic, with a yearning to somehow, in some way, return to those days of yesteryear and grasp, at least for a moment, some of the wonder and magic of our youth, when we dreamed of mystical buffalo and hunted with the Indians.

What the prairies were like is mostly conjecture. Our information has to be gleaned from the few scattered remnants, and experienced vicariously from diaries, journals and recollections of early settlers and travelers.

Lawrence Auld of Cedar Falls, Iowa, recalls stories related to him of people riding from Oskaloosa to Des Moines on horseback, in tall-grass without seeing a single tree. That same journey today on Route 163 will take you through Prairie City, a name memorializing something that no longer exists.

Often prairie recollections tell of grass so tall that people on horseback or in wagons could not be seen. Richard Brewer (1970) maintains that the image of a man on horseback hidden by the tall-grass recurs in almost every account. The memory is faithful, but partial. Big bluestem and Indian grass on moist sites, and slough grass, blue-joint and <u>Phragmites</u> on wetter ones, did reach heights of six to eight feet or more; but little bluestem, the dominant grass on higher and drier areas, grew only to two or three feet. Even on moister sites, the image is one of late summer and autumn. In early spring the shorter flowers stood out among the old grass. The tall stalks of the preceding year were flattened and matted by the winter snow, or gone altogether, consumed by prairie fire.

As the country was settled in the westward movement the settlers moved away from the river-fringing forests slowly. The forests provided wood for building, tools and implements, as well as fuel. But the attachment to the woodlands seemingly went beyond physical needs. Washington Irving (1859), writing of his prairie tour, expressed this affinity for the woodlands in the following way: "To one unaccustomed to it there is something inexpressibly lonely in the solitude of the prairie. The loneliness of a forest seems nothing to it. There the view is shut in by the trees and the imagination is left to picture some livelier scene beyond. But here we have the immense extent to landscape without a sign of human existence. We have the consciousness of being far, far beyond the bounds of human habitation . . .". John Madson (1972) extends this thought, "But the greater part may have been a profound insecurity--of being part of something wholly new, with no ancestral precedents in Europe or New England. In a forest man is partly hidden; he has carved a niche with sheltering hills and walls of trees. There is intimacy in a forest. But not on a prairie; there are no walls on a prairie. The prairie man and woman and their puny fields were exposed to a vast and pitiless sky. There was no smugness, no security, nothing to shield the family; a man was alone and naked bared to an openness of terrifying intensity and magnitude."

The main character of Bess Streeter Aldrich's (1928) book, <u>A Lantern in Her Hand</u>, notes the forest-prairie contrast while camped near Nebraska City, Nebraska: "It made Abbie think of a night years ago when they camped west of Dubuque on the journey from Illinois when she was eight, and yet this was different. Then, they had been close to the woods; the sheltering woods. They had heard all the little night creatures at work, all the tiny rustlings of the timber. But this paradoxically, was a silent noise. There was complete silence,-save for those distant coyotes. Silence,-save for a faint sound of shivering grass. Silence; so deep, that it roared in its vast vacuum. Silence - grass - stars. The group around the fire seemed suddenly too small to be alone in the still vastness, too inadequate and helpless."

Even as the people changed the prairie, by plowing and tilling and bringing trees to their homesites, the composed of many different species of native American plants. It appears as an inextricable mass of endless variable vegetation. One glories in its beauty, its diversity, and the ever changing patterns of its floral arrangements. But he is awed by its immensity, its complexity and the seeming impossibility of understanding and describing it. After certain principles and facts become clear, however, one comes not only to know and understand the grasslands but also to delight in them and to love them."

Jim and Alice Wilson (1967) relay the statement of a farmer, "Sometimes I feel the whole world's flying to pieces. Then I take my dog and go out in my beautiful grass, and I know it isn't so." In addition, Jim has often talked of the need for "people pastures."

My friend Arnold Webster probably puts it in the most straightforward manner, "After spending an hour on the prairie I can begin to feel the cussedness run out of me."

No doubt each of us relates to certain aspects of the prairie that have special meaning for them. For me the plants of the prairie invoke feelings of awe and wonderment as well as continuity with the past. Nothing is more relaxing than lying on your back in late summer and viewing a deep blue sky through the outstretched turkeyfeet of big bluestem. What can compare with the carpeted beauty of rods of black-eyed Susan or blazing star stretching toward the horizon? Who can express the feelings that well up inside upon seeing the white fringed prairie orchid for the first, and perhaps only, time? Brilliant orange is predominant when one discovers the Turk's cap lily in a swale or observes butterfly weed on a hot, dry, late summer afternoon. The uniqueness of the flowers and fruit of prairie smoke, rattlesnake master and Indian plantain account for at least a part of their beauty. The delicate beauty of an individual shooting star flower is matched only by the awe inspiring visual impact in late May of hundreds upon hundreds of them forming a white to lavender patchwork quilt. A September day is brightened by the colorful contrast of the giant blue lobelia or purple gentian against the drying grass. One has to admire the tenacity of purple coneflowers that have re-established along a roadside or railroad right-of-way as an annual proclamation of once existing prairie. Aldo Leopold's (1949) writing has undoubtedly influenced me so that the compass plant stands out as a symbol of the vanishing prairie.

Most would agree that the prairie is valuable; the problem is how to determine the value. John Madson and Aldo Leopold probably articulate this problem best. Leopold (1953) writes, "What is the most valuable part of the prairie . . . the black prairie soil was built by the prairie plants, a hundred distinctive species of grasses, herbs, and shrubs; by the prairie fungi, insects, and bacteria; by the prairie mammals and birds, all interlocked in one humming community of co-operations and competition, one biota. This biota, through ten thousand years of living and dying, burning and growing, preying and fleeing, freezing and thawing, built that dark and bloody ground we call prairie. Our grandfathers did not, could not, know the origin of their prairie empire. They killed off the prairie fauna and they drove the flora to a last refuge on railroad embankments and roadsides."

Madson (1972) puts it in more recent terms, "We spent our tall-grass prairie with a prodigal hand, and it probably had to be that way, for these are the richest farm soils in the world. There were certain wilderness things that were fated to be spent almost to the vanishing point: bison in short-grass plains, lobos and grizzlies in settled cattle country--and the vistas of true prairie.

"Spending is one thing; bankruptcy is another. To squander the last stands of true prairie would wipe out a valuable index to original quality. It is important that our agronomists, botanists, zoologists, and soil specialists have reference points to the original plants and soils of our most valuable ecosystem. We may someday have to rebuild those soils, or try to. Native prairie is a baseline from which creative research can depart, and return for reference. We'd never dream of melting down the platinum meter in Paris and converting it to jewelry; it is the master rule, an original measurement upon which so much engineering and science are based. And so, in an even greater sense, is native prairie."

We must "understand" the prairie to protect it. However, it is difficult to grasp the significance of a vanishing heritage before it is gone.

Tall-grass prairie is the most difficult of all native America to conserve, it is the world's most valuable farm soil. I think the pragmatic views of my grandfather and my more romantic viewpoint exemplify the dilemma. Our blood was the same, but he was certainly tempered in a different crucible than I. He was raised near the Grand Prairie of Illinois in Stark County, on a farm purchased by his grandfather in 1849. He faced hardship at an early age, with his father dying of "lung fever" before his third birthday, and his nineteen-year-old brother of mumps one year later. He helped another brother homestead in South Dakota before emigrating to southeast Iowa. He had considerable experience with prairies and was not especially romantically inclined toward them. When I pressed him for comments on the prairie, he did recall that in Dakota they had to leave a section for the school. I loved my grandfather, and when we buried him in January, 1974, at 88 years of age, I was delighted to see a few straggling remnants of big bluestem surviving near gravestones in the small country cemetery of his final resting place. When I called this to the attention of a relative he replied, "Yes, this place has been let go, it sure needs some care."

I still haven't found a complete explanation for my own interest in prairies, a necessary prerequisite to discerning the interest of others. Maybe I'm like Paul Sears (1969), who suggests an analogy of alcohol and open spaces as an explanation for his affliction. He states: "Alcohol, we are told with some truth, is likely to have enhanced attraction for people reared on total abstinence. Something of the sort may explain my lifelong interest in prairies and other treeless areas. I grew up in northern Ohio where even after a century of dogged cutting, trees were never out of sight."

A similar case of familiarity with wooded areas can be made for me. I spent the most vivid, impressionable, years of my life in the watershed of Sugar Creek in southeastern Iowa, with sugar maple (source of the name of the creek) and other trees in ample supply, and didn't really venture out into the prairie until later in life. It has been suggested that Frederic Remington could portray the West better in his paintings and writings because he was a visitor and not a native son (Hedgepeth 1975). Perhaps as a late-comer to the prairie and not an inhabitant, I can prairie changed the people. The prairie and the vastness beyond it were uniquely American. The men and women who settled there were also unique, or became so, and John Madson (1972) suggests they may have been the first total, genuine Americans, although a good case could be made for some of the plains Indians. In any event, they were new people in a new land--and to the European man such people and land had not been known before. The struggle between man and this vast land was fierce and long. But aided by John Deere's sod-breaking steel plow and other technological tools it would appear that man has gained the upper hand. Certainly in terms of acres under cultivation and species reduced the score stands heavily in man's favor. However, riding on the winds of a prairie blizzard, the land still occasionally strikes back to remind man that he had best keep up his technological guard or suffer the consequences. In addition, stories of the ashen skies of the thirties serve as a constant reminder that technology may not be enough if we too far overstep our bounds.

Written reactions to the prairie varied. Some loved it and spoke of it in glowing terms, while there were those who hated the prairie, and spoke of it as "a fearful place."

Rolvaag's (1927) chief character, Beret, shows the distress of one who could not take root in the new soil, and the author eventually sacrifices Per Hansa apparently to appease the spirit of the prairie.

As one reads Laura Ingalls Wilder, the impression is that she was awed by the prairie, but loved it very much. In Little House On The Prairie (1935) she writes, "There was only the enormous, empty prairie, with grasses blowing in waves of light and shadow across it, and the great blue sky above, and birds flying up from it and singing with joy because the sun was rising. And on the whole enormous prairie there was no sign that any other human being had ever been there . . ." ". . . they climbed to the wagon seat again and rode away from the creek. Up through the woods and hills they rode again, to the High Prairie where the winds were always blowing and the grasses seemed to sing and whisper and laugh. They had had a wonderful time in the creek bottoms. But Laura liked the High Prairie best. The prairie was so wide and sweet and clean."

James Michener's (1974) character, Paul Garrett, may have assessed Francis Parkman correctly in the following comment, "He could turn a phrase rather well, but in human understanding he was pitifully deficient." However, Parkman (1847) was a keen observer and presented a rather picturesque but realistic view of the prairie. He writes of its beauty, but also speaks of some of the less attractive aspects.

On leaving the high bluffs of the Missouri River, Parkman (1847) notes the following: "On the left stretched the prairie, rising into swells and undulations, thickly sprinkled with groves, or gracefully expanding into wide grassy basins, of miles in extent; while its curvatures, swelling against the horizon, were often surmounted by lines of sunny woods; a scene to which the freshness of the season and the peculiar mellowness of the atmosphere gave additional softness." Later he writes, "Should any of my readers ever be impelled to visit the prairies, and should he choose the route of the Platte (the best, perhaps, that can be adopted), I can assure him that he need not think to enter at once upon the paradise of his imagination. . . the scenery though tame, is graceful and pleasing. Here are level plains, too wide for the eye to measure; green undulations, like motionless swells of the ocean; abundance of streams, followed through all their winding by lines of woods and scattered groves. But let him be as enthusiastic as he may, he will find enough to damp his ardor. His wagon will stick in the mud; his horses will break loose; harness will give away; and axle-trees prove unsound. His bed will be a soft one, consisting often of black mud of the richest consistency." Still later on the St. Joseph trail he commented, "The journey was monotonous. One day we rode on for hours without seeing a tree or bush; before, behind, and on either side, stretched the vast expanse, rolling in a succession of graceful swells, covered with unbroken fresh green grass. Here and there a crow, a raven, or a turkey-buzzard, relieved the uniformity."

We need the prairie because it is a part of our past. Much of the biological inheritance of the naked ape of Desmond Morris (1967) was developed in the forests, but most of our cultural inheritance is tied to the savannahs of Africa. Nature in our daily lives may well be an inherent biological necessity, not a luxury. Millions of years of inheritance and culture have programmed us to a natural habitat of fresh air and a varied wild landscape unspoiled by the disturbance of civilization. Not only is the physical impact of the prairie important, but man's psychological well-being may well rest upon recapturing the essence of the prairie.

Loren Eisely (1970) presents the case in the following manner: "When I was a small boy I once lived near a brackish stream that wandered over the interminable salt flats south of our town. Between occasional floods the area became a giant sunflower forest, taller than the head of a man. Child gangs roved this wilderness, and guerrilla combats with sunflower spears sometimes took place when boys from the other side of the marsh ambushed the hidden trails . . .

"The sunflower forest of personal and racial childhood is relived in every human generation. One reaches the high ground, and all is quiet in the shaden reeds. The nodding golden flowers spring up indifferently behind us, and the way backward is lost when finally we turn to look. There is something unutterably secretive involved in man's intrusion into his second world, into the mutable domain of thought . . .

"Today men's mounting numbers and his technological power to pollute his environment reveal a single demanding necessity: the necessity for him consciously to reenter and preserve, for his own safety, the old first worlds from which he originally emerged. His second world, drawn from his own brain, has brought him far, but it cannot take him out of nature, nor can he live by escaping into his second world alone. He must now incorporate from the wisdom of the axial thinkers an ethic, not alone directed toward his fellows, but extended to the living world around him. He must make, by way of his cultural world, an actual conscious reentry into the sunflower forest he had though merely to exploit or abandon. He must do this in order to survive. If he succeeds he will, perhaps, have created a third world which combines elements of the original two . . ."

John Weaver (1954) introduces the North American Prairie with this opening statement: "Prairie is better appreciate its natural wonder.

In any case, when all is said and done, if I have my druthers, you can bury me in one of those few township cemeteries that time has passed by, and the only care I request is an occasional burning to keep out invading weeds and trees.

LITERATURE CITED

Aldrich, Bess Streeter. 1928. A lantern in her hand, Appleton-Century-Crofts, Inc., New York. p. 72.

Brewer, Richard. 1970. Death by the plow. Nat. Hist. 79(7):28-33, 110.

Eisely, Loren. 1970. The invisible pyramid. Charles Scribner's Sons, N.Y. pp. 149, 154, 155.

Hedgepeth, Don. 1975. Frederic Remington - Nature in the old west. Field and Stream. 79(11):64, 65, 162-168.

Hirsch, Audrey. 1975. Midwestern mystique - The "Sea of Grass." Des Moines Register, Des Moines, Iowa, 28 Dec.

Irving, Washington. 1859. A tour on the prairies. Reprinted 1956, with 1935 Introduction, Editorial comments by J. F. McDermott. Univ. Oklahoma Press, Norman. p. 175.

Leopold, Aldo. 1949. A Sand County almanac. Oxford Univ. Press, New York. pp. 44-50.

Leopold, Aldo. 1953. Round River. Ed. by Luna B. Leopold. Oxford Univ. Press, New York. p. 148.

Madson, John. 1972. The running country. Audubon. 74(4):4-19.

Michener, James A. 1974. Centennial. Random House, New York. pp. 902, 903.

Morris, Desmond. 1967. The naked ape. McGraw-Hill Book Co., New York.

Parkman, Francis. 1847. The Oregon trail. Reprinted 1964 with prefaces from 1872 and 1892 editions, Airmont Publishing Co., New York. pp. 27, 33, 37.

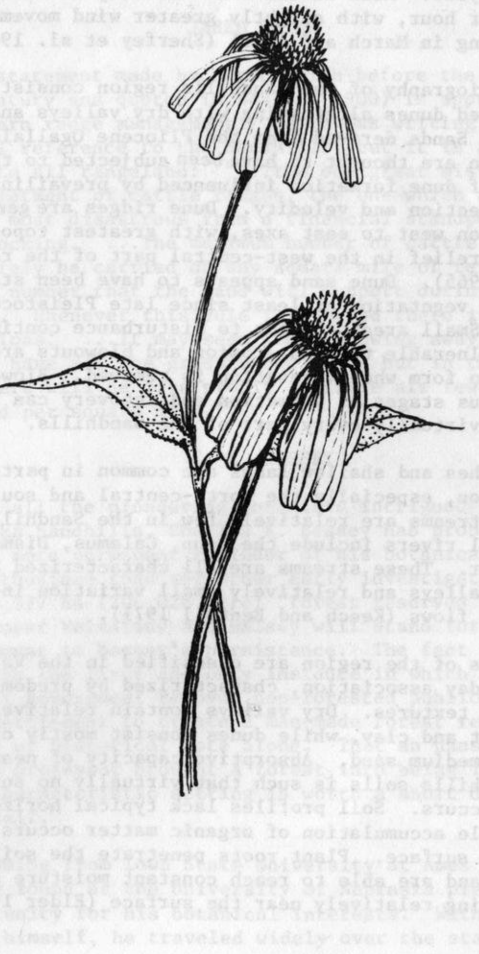
Rölvaag, O. E. 1927. Giants in the earth. Harper and Row, New York.

Sears, Paul. 1969. Lands beyond the forest. Prentice-Hall, Englewood Cliffs, N.J. p. 3.

Weaver, John E. 1954. North American prairie. Johnsen Publishing Co., Lincoln, Nebraska. p. vii.

Wilder, Laura Ingalls. 1935. Little house on the prairie. Harper and Row, New York. pp. 40, 112.

Wilson, J. and A. Wilson. 1967. Grassland. Wide Skies Press, Polk, Nebraska.



BOTANICAL PIONEERS OF THE NEBRASKA SANDHILLS

Curtis M. Twedt
and
Carl W. Wolfe

Nebraska Game and Parks Commission
2200 North 33rd
Lincoln, NE 68503

ABSTRACT

The contributions of several early explorers and botanists to our present knowledge of Nebraska Sandhills ecology are discussed. Particular emphasis is placed on C. E. Bessey and R. J. Pool.

INTRODUCTION

The Nebraska Sandhills comprise an area of about 5,200 square kilometers, extending from about 98° 30' to 103° W. Northern and southern boundaries are parallel with the Niobrara and Platt River valleys, respectively. The Sandhills merge with the Loess Hills physiographic region at the southeast, resulting in irregular interfaces of low dunes with clay bluffs and canyons of the latter region (Elder 1969).

Average annual precipitation ranges from approximately 61 cm in the east to less than 40 cm in the west. About 75 percent of annual precipitation occurs during the period April through October. Temperature extremes range from more than 38 C to -29 C during an average year. Mean annual wind velocity is about 16 km per hour, with slightly greater wind movement prevailing in March and April (Sherfey et al. 1965).

Physiography of the Sandhills region consists of stabilized dunes alternating with dry valleys and basins. Sands derived from the Pliocene Ogallala formation are thought to have been subjected to three cycles of dune formation influenced by prevailing wind direction and velocity. Dune ridges are generally aligned on west to east axes, with greatest topographic relief in the west-central part of the region (Smith 1965). Dune sand appears to have been stabilized by vegetation at least since late Pleistocene times. Small areas subject to disturbance continue to be vulnerable to wind erosion and blowouts are likely to form when vegetation is removed. Blowouts in various stages of formation and recovery can be seen in virtually every part of the Sandhills.

Marshes and shallow lakes are common in parts of the region, especially the north-central and southwest. Streams are relatively few in the Sandhills; principal rivers include the Loup, Calamus, Dismal, and Cedar. These streams are all characterized by narrow valleys and relatively small variation in seasonal flows (Keech and Bentall 1971).

Soils of the region are classified in the Valentine-Dunday association, characterized by predominantly sandy textures. Dry valleys contain relatively more silt and clay, while dunes consist mostly of fine to medium sand. Absorptive capacity of nearly all Sandhills soils is such that virtually no surface runoff occurs. Soil profiles lack typical horizons and little accumulation of organic matter occurs at or near the surface. Plant roots penetrate the soil readily and are able to reach constant moisture supplies lying relatively near the surface (Elder 1969).

Grasses comprise the dominant growth form of the region's vegetation. Kuchler (1964) termed the potential natural vegetation of the area Sandhills Grassland, with Andropogon and Calamovilfa the diagnostic genera. Panicum, Stipa, and Eragrostis are also important components. Typical forb constituents include members of the Leguminosae, Compositae, Polygonaceae, and Asclepidaceae. There are few species of woody plants in the region, but low shrubs make up significant parts of the vegetation of all soil and topographic combinations. Rose (Rosa spp.), leadplant (Amorpha canescens), sandcherry (Prunus besseyi), and redroot (Ceanothus ovatus) are among the more common shrubs. The narrow floodplains and canyon walls of major streams support sparse to moderate stands of mixed deciduous trees and redcedar (Juniperus spp.). Small stands of hackberry (Celtis occidentalis) are found far from stream valleys, usually on middle portions of steep south slopes.

The Sandhills was not a region that invited the exploration or scientific trips often associated with other parts of the continent. Had it not been for the river systems that originated in the "hills", it is doubtful that this area would have been explored until well into the 1800's. This unique and often harsh region did see, though, a number of early-day travelers, some not particularly inclined toward the botanical aspects, but of keen observation so that reasonably good descriptions were set down. Later, many of the "classic" botanists recorded detailed observations on the ecosystems of the region, some so complete that little improvement has been made on their early works.

JAMES MACKAY

A few early explorers are thought to have crossed central Nebraska -- Bourgmond in 1714, Villasur in 1720, and the Mallet brothers in 1739 -- but nothing is known about their routes (Diller 1955). James Mackay was one of the first of these early explorers and botanists of the Sandhills to record his impressions. Mackay was the leader of an expedition of the Upper Missouri Company of St. Louis, which established a post in extreme northeastern Nebraska. Fragmentary natural history notes by Mackay, written in 1796, represent the first recorded observations of the Nebraska Sandhills: "Great deserts of drifting sand without trees, soil, rocks, water, or animals of any kind, excepting some little varicolored turtles, of which there are vast numbers...Found here the middle part of the thighbone of an animal, the large end of which was 7 inches (about 17.75 cm) in diameter and the other 6 3/4 inches (16.1 cm)...In these marshes there is some wild rice...Sandy hilly country."

LT. G. K. WARREN

Lt. Warren reported on two expeditions through the Sandhills. Warren's 1855 route was the middle part of an exploration from Ft. Pierre on the Missouri River to Ft. Kearny on the Platte. His contingent left Ft. Pierre August 9 and reached Ft. Kearny August 25. Camp sites in and near the Sandhills included the

Niobrara Valley on August 14, near Calamus River August 17, and on Middle Loup River August 19.

Warren's 1857 expedition left Sioux City on July 6 for the mouth of the Loup Fork of the Platte River. From here, Warren, in company with J. Hudson Snowden, a topographer, proceeded westward. The command made its way slowly through quicksand and terrain made difficult by the numerous creeks emptying into the Platte. Within 50 miles, the Loup Fork closed down to a gorge through which the wagons could not pass.

At this point, a teamster member of the party came down with typhoid fever. To allow recovery, the expedition halted and Warren spent time investigating the nature of the surrounding country. The harsh nature of the Sandhills certainly made its effects felt. Warren's account in early August indicated "We have now traced the river (Loup) from end to end and found the impracticality for almost any purpose so marked that it seems like a great waste of time to have made the exertion we have. Our greatest wish is to get away from it (the Sandhills) as soon as possible and never return."

While Warren moved on with his men to Ft. Laramie, Snowden apparently stayed in the region of the Upper Niobrara until rejoining Warren on October 15. During this time Snowden had thoroughly examined, mapped and studied a large area of land bordering the Niobrara.

Assigned to Washington in late 1857, Warren labored almost a year to prepare his reports on travels in the Missouri River basin country. Certainly his "Preliminary Report of Exploration in Nebraska and Dakota" provided an important cataloging of the resources of the Sandhills, even though much of the identification and commentary on the flora and fauna was provided by others.

Chapters covering the general routes of travel, geography and geology, climate, descriptions of the river systems, Indians and the military, and natural history make interesting reading. The catalog of plants collected during the three years of exploration shows a total of 593 species, with notes on distribution, abundance and occasional references to medicinal or ritual use among the natives. The majority of collections were made adjacent to the Missouri River, but central Nebraska is well represented, especially the areas adjacent to the Platte and Loup rivers (Warren 1875).

F. V. HAYDEN

F. V. Hayden, later of the U.S. Geological Survey, accompanied Warren's 1857 exploration in the capacity of geologist and naturalist. In the late 1860's, Hayden recorded a number of botanical observations during the course of extensive geological explorations in the Great Plains. Hayden described the geographical boundaries of the Sandhills as the Niobrara River at the north and the Platte River at the south and estimated their area at 20,000 square miles (about 5,200 square kilometers). Among his writings, there are references to the alkaline marshes and shallow lakes in the region, which he distinguished by lack of vegetation around the borders. Hayden's description of Sandhills blowouts, though brief, contains the essential features of this landform: "The whole surface is dotted over with conical hills of moving sand. These hills often look like craters or small basins, the wind whirling and, as it were, scooping out the sand, leaving innumerable depressions with a well-defined circular rim." He noted the adaptation of the region's common plants to sandy substrate and made reference to hillsides literally covered with <u>Yucca</u>. Hayden also emphasized that the region was not suited to intensive agriculture, and that even grazing would have limitations (Hayden 1873).

P. A. RYDBERG

P. A. Rydberg (1895) conducted a three-month botanical exploration of three counties in the central Sandhills in the summer of 1893. During the course of his investigation, he collected 600 herbarium specimens (about 200 species) in 16 localities. Rydberg described four topographic types in the region: river valleys, dunes, dry valleys, and wet meadows. Among the dominant plant species, he singled out sand bluestem (<u>Andropogon hallii</u>), little bluestem (<u>A. scoparius</u>), needle-and-thread (<u>Stipa comata</u>), one sedge, four shrubs, and 22 forbs (including three legumes, four composites, and three milkweeds). In the dry valley site, 12 additional forb species were identified, while the aquatic flora included three species each of duckweek, pondweed, and emergent rooted plants. Rydberg also enumerated 24 "weeds", both native and introduced, which he observed thriving on disturbed sites. He further speculated optimistically about the possibilities of large-scale coniferous tree plantings, as well as adding exotic grasses and legumes to the native forage plants.

JARED SMITH

A statement made by Jared Smith before the turn of the century and quoted in Bessey (1900) is appropriate in modern range management. Smith was writing with special reference to the Sandhills, but it is applicable to all rangeland: "...the one great mistake in the treatment of cattle ranges, the one which always proves most disastrous from a financial standpoint, is overstocking. ...The maximum number of cattle that can safely be carried on any square mile of territory is the number that the land will support during a poor season. Whenever this rule is ignored there is bound to be loss. ...It may seem like throwing away money not to have all the grass eaten down, but in the long run there will be more profit if there are fewer head carried per square mile."

C. E. BESSEY

Of all the pioneering botanists intrigued by the Nebraska Sandhills, Charles E. Bessey has probably left a more permanent reminder of his botanical zeal and enthusiasm than any other early investigator. The 83,377 ha (206,028 acre) "forest reserves" set aside near Valentine and Halsey will stand forever as a monument to Bessey's persistence. The fact that this was the first and only instance in which the federal government removed non-forested public domain from settlement to create a man-made forest reserve is worthy of historical note alone. That an unassuming botany professor brought a forest into being in such an uncharacteristic setting is worth a short discourse by itself.

Coming from Iowa State University at Ames in 1884, Bessey found at the University of Nebraska plenty of opportunity for his botanical interests. With students or by himself, he traveled widely over the state, collecting and describing Nebraska flora. His interest in the vegetation of the Sandhills was high from the very beginning. One aspect of Bessey's studies included digging test holes in many places. At each digging he always found moisture within a few centimeters of the surface, no matter how dry or hot the topsoil. Recalling similar conditions in Michigan, it seemed "quite likely" to him that the moist soil of the Sandhills would bear forests once trees were planted. When he found western yellow pine and red cedar growing in widely scattered localities in the Sandhills, he soon became convinced that selected species of trees would grow in the region. Reports and recommendations for tree planting in the Sandhills were not long in coming. As a member of a joint committee from the State Horticultural Society and the State Board of Agriculture, he petitioned the state legislature in 1887 to set aside tracts of land in the Sandhills for tree planting.

Bessey's repeated recommendation and urgings were not exactly popular with the ranchers and stockmen in the region. They insisted that forests were plentiful elsewhere, and that public domain grasslands were established for grazing and should not be fenced off for forest experiments. Undaunted by local opposition or federal coolness, Bessey persisted in his convictions.

After making so many people miserable about the planting of pines in the Sandhills, Bessey's appeal was rewarded with a peculiar reaction from Washington. In present day vernacular it could be equated to a bureaucratic stall. If this was in fact the case, the whole scheme to get Bessey off their backs went awry.

In January, 1891, the Director of the Division of Forestry, Dr. B. E. Fernow, contacted Bessey indicating he (the government) was ready to make the experiment of planting pines in the Sandhills, if Bessey could make land available for such purposes. Initially provoked because his duties at the University would not allow him to take care of the project and because he didn't have any land to turn over to Fernow for the government's use, Bessey "expressed himself rather emphatically as he walked up and down the corridors of Nebraska Hall". As fate would have it, a colleague and professor of entomology, Lawrence Bruner owned, along with his brothers, some land in southwestern Holt County, right in the heart of the Sandhills. Bruner's offer of the land paved the way for an agreement with the Division of Forestry. By the end of 1892, four plots of 1/4-acre each had been planted with four species. The harsh climate of the Sandhills took its toll on the new plantings. Where one plot had been plowed, the trees died and a blowout developed. Western yellow pine and jack pine survived where they had been furrow-planted, and reports were favorable. After several years, the plantation was ignored, and no further reports were made. In the meantime, Bessey continued to campaign for forestation of the Sandhills, making continued pleas to the State Horticultural Society and through reports to the State Board of Agriculture.

Suddenly, the fruits of Bessey's ceaseless lobbying showed promise. In 1901, a reconnaissance party of the U.S. Bureau of Forestry arrived to examine forest conditions in Nebraska. Much to the surprise of even Bessey, they found trees planted 10 years earlier on the all-but-forgotten Bruner tract had attained heights of 18 to 20 feet, and had formed a dense thicket on the rolling Sandhills north of Swan Lake. When Bessey learned of this, and of the party leader's (William L. Hall) favorable impressions, he realized that his long-held dream was close to reality. He lobbied with anybody who could possibly influence a decision, beginning with prominent citizens and ending with Gifford Pinchot, who had recently taken over as Chief of the Bureau of Forestry, USDA. With a favorable report by the government party, the long quest ended in April 1902 when Theodore Roosevelt set aside two reserves totaling 83,377 ha. In later years, the 38,850 ha tract near Halsey was designated the Bessey Division; the 44,516 ha tract near Nenzel the Niobrara Division.

Tree planting began in 1903 and progressed through the early 1900's until approximately 12,140 ha had been planted. While jack pine and Scotch pine did not fare well during the droughty 1930's, ponderosa pine and redcedar demonstrated the potential of the sandy dunes for growing trees.

Other ecological considerations aside, the Bessey Division forest is impressive as an unusual botanical entity in a unique setting. While one might question whether Bessey's quest was wise in light of today's movement toward (or back to) native vegetation, one lesson might be had for us all in examining his contributions. By today's standards he might be classified a "radical environmentalist", but his dogged persistence, patience, and committment to battle all the way to the top, clashing with vested interest groups and top government officials, made his dreamed-of changes possible. Bessey's philosophy of total commitment serves today as a standard in the even more important battle for environmental quality.

R. J. POOL

The most intensive early study of Sandhills vegetation was done as a doctoral dissertation by R. J. Pool and was published in the University of Minnesota Botanical Studies (Pool 1914). The study was prefaced with a concise treatment of the region's geology and climate, with the main part presenting detailed descriptions of plant communities. Environmental influences on vegetation received considerable emphasis. The arrangement of plant assemblages, following the approach of F. E. Clements, are summarized below.

I. Upland Formations
   - A. Prairie grass formation
     1. Bunchgrass association
     2. <u>Muhlenbergia</u> association
     3. Blowout association
     4. Speargrass association
     5. Wiregrass association
   - B. Short grass formation
     1. Grama-buffalograss association
   - C. Woodland formation
     1. Linden-cedar-ironwood-ash association
   - D. Yellow pine formation

II. Lowland Formations
   - A. Water plant formation
     1. Pondweed association
     2. Waterlily association
     3. Stonewort-naiad association
   - B. Marsh formation
     1. Bulrush-reed association
     2. Smartweed association
     3. Streamside marsh association

C. Meadow formation
  1. Rush-sedge association
  2. Water hemlock association
  3. Fern meadow association
  4. Hay meadow association
  5. Willow thicket association

Pool theorized on geographic origins of floral components which co-mingled in the Sandhills. He stated that elements of eastern prairie, western foothills, and western montane floras were associated with what was referred to as the "proper" vegetation which had evolved in response to environmental conditions. No detailed descriptions or lists of the various associations will be presented, but a few examples are discussed in the following paragraphs.

The bunchgrass association, which occurs on most upland sites, is dominated by sand bluestem (Andropogon hallii) and little bluestem (A. scoparius). Other "principal" species included three grasses, four shrubs, and four species of forbs. The list is rounded out with 90 "secondary" species.

The blowout association, more or less limited to plants adapted to this harsh environment, is dominated by sandreed (Calamovilfa longifolia), blowout grass (Redfieldia flexuosa), and lemon scurfpea (Psoralea lanceolata). All of these have well-developed rhizomes which are able to grow rapidly, thus anchoring the shifting sand.

Woodlands described by Pool include some that have extremely limited ranges. The largest assemblages of woody plants are found at the northern fringe of the Sandhills, especially in association with spring-fed tributaries of the Niobrara River. In the central Sandhills, trees and shrubs are more likely to be limited to about a dozen species.

Rush-sedge meadow represents a nearly complete departure from the upland herbaceaus vegetation. Dominant elements include five species of Juncus and four Eleocharis spp.. About 50 "secondary" species are also listed, only a few of which occur sparingly on other sites having less favorable moisture conditions.

The hay meadow association was described separately due to Pool's recognition of the economic importance of this vegetation type. All 13 dominant species are grasses, with some occurring in wetter or dryer situations. Of the 39 "associated" species, several also occur on prairie sites. Part of the variability of hay meadow vegetation is due to the presence of topographically low marshes or the rush-sedge type, while the "upper" edges merge with lower prairie slopes.

In addition to observation abilities, Pool also possessed a great talent for teaching. During his tenure at the University of Nebraska, field botany remained one of his primary interests. He was also a firm advocate of photographic documentation, which was used extensively in his own investigations and those of his students. Several hundred glass plate negatives and lantern slides, with date and location information, remain in the collection of the State Museum Herbarium.

SUMMARY

In retrospect, the high points in the careers of the scientists discussed in this review represent but a fraction of their contributions to humanity. They were pioneers in the truest sense of the word. Travel was by foot, on horseback or by horse-drawn vehicle. Equipment and scientific literature were limited, but the results produced were significant. Thorough observation and the ability or organize data in a meaningful published form stand out in all their professional efforts. Though modified in detail, their findings remain valid in principle.

ACKNOWLEDGEMENTS

We wish to express our thanks to Barbara Paullin for typing the manuscript. Many of the slides used in the conference presentation were prepared from negatives and slides loaned to us by Steve Chruchill, Research Assistant, Nebraska State Museum.

LITERATURE CITED

Aughey, S. 1880. Sketches of the physical geography and geology of Nebraska. Daily Republican and Job Office, Omaha.

Bessey, C.E. 1893. The reforesting of the Sand Hills. Ann. Rept. Nebr. State Bd. Agric. pp. 94-97.

Bessey, C.E. 1900. Agriculture possibilities of western Nebraska. Ann. Rept. Nebr. State Bd. Agric. pp. 75-116.

Diller, A. 1955. James Mackay's journey in Nebraska in 1796. Nebr. History 36:123-128.

Elden, J.A. 1969. Soils of Nebraska. Univ. Nebr. Conserv. Sur. Div. Resource Rept. No. 2. 60 pp.

Flanagan, V.J. 1970. Gouverneur Kemble Warren: Explorer of the Nebraska Territory. Nebr. History 51:171-198.

Hayden, F.V. 1873. First annual report of the U.S. Geological survey of the Territories - Nebraska, 1867. U.S. Govt. Printing Off., Washington. pp. 1-64.

Keech, C.F., and R. Bentall. 1971. Dunes on the plains: The Sandhill region of Nebraska. Univ. Nebr. Conserv. Sur. Div. Resourse Rept. No. 4. 18 pp.

Kuchler, A.W. 1964. Potential natural vegetation of the conterminous United States. Amer. Geog. Soc. Spec. Publ. No. 36. 155 pp + map.

Pool, R.J. 1914. A study of the vegetation of the Sandhills of Nebraska. Univ. Minn. Bot. Stud. 4:189-312.

Pool, R.J. 1915. A brief sketch of the life and work of Charles Edwin Bessey. Am. J. Bot 2:505-518.

Pool, R.J. 1953. Fifty years on the Nebraska National Forest. Nebr. History 34:139-179.

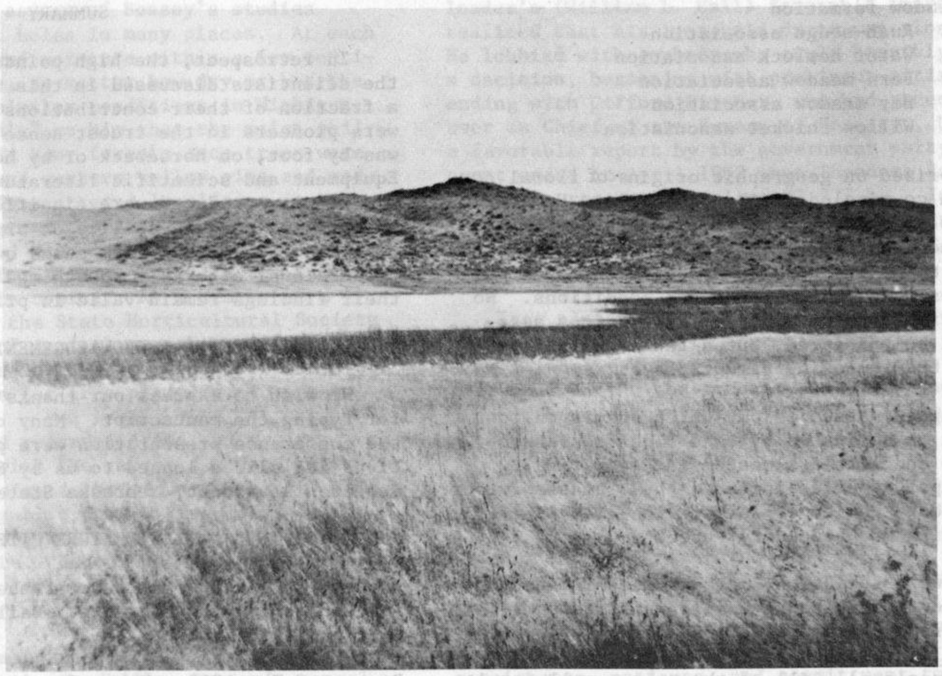


Fig. 1. Shallow lakes and marshes are common in the Sandhills. Clear Lake; Cherry County; July, 1912.

Fig. 2. Jared Smith, USDA botanist, issued warnings before 1900 about the dangers of overgrazing. Photo taken in Thomas County; 1912.

Rydberg, P.A. 1895. Flora of the Sandhills of Nebraska. Contrib. U.S. Nat. Herbarium. 3:133-203 + map.

Sherfey, L.E., C. Fox, and J. Nishimura. 1965. Soil survey of Thomas County, Nebraska. U.S. Dept. Agric. Series 1961, No. 29. 44 pp. + maps and aerial photographs.

Smith, H.T.U. 1965. Dune morphology and chronology in central and western Nebraska. J. Geol. 73:557-578.

Walsh, Thomas R. 1972. The American green of Charles Bessey. Nebr. History 53:35-57.

Warren, G.K. 1875. Preliminary report of explorations in Nebraska and Dakota in the years 1855, '56, and '57. Engineer Dept., U.S. Army. 125 pp.

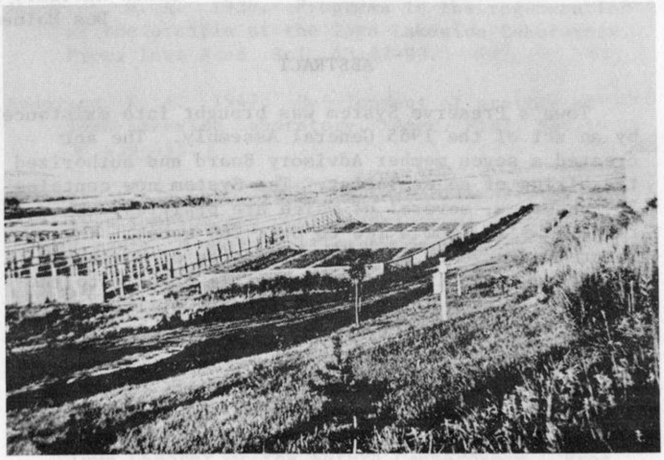


Fig. 3. U.S. Forest Service nursery near Halsey; 1908.

Fig. 4. Native ponderosa pine; north-central Cherry County; ca. 1910.

PRAIRIE PRESERVATION IN IOWA - HISTORY, PRESENT STATUS AND FUTURE PLANS

Dean M. Roosa
Board Ecologist
State Advisory Board for Preserves
Des Moines, Iowa 50319

ABSTRACT

Iowa's Preserve System was brought into existence by an act of the 1965 General Assembly. The act created a seven member Advisory Board and authorized the hiring of an ecologist. The System now contains 30 preserves, several of which are prairies. These range in size from a few to over 200 acres. The Nature Conservancy and the University of Northern Iowa have recently dedicated prairie areas into the Preserves system. These prairies are utilized for research and education, and an active controlled burning program is in effect.

PRAIRIE PRESERVATION IN IOWA

At the time of settlement, Iowa was approximately 85 percent prairie (Dick-Peddie 1953), totaling about 12.1 million ha (30 million acres). It had nearly all disappeared by 1933 when the first movement toward preservation was made. The first overture was made in the "Report on the Twenty-five Year Conservation Plan" (Crane and Olcott 1933) which called for a prairie preserve as part of an overall structured plan for the state. However, interest in prairies preceded any movement to preserve them. Dr. Bohumil Shimek, of the University of Iowa, wrote a series of articles on restoration, distribution and origin of Iowa prairies. Although probably best known as a malacologist and soil scientist, Shimek collected thousands of plants from all Iowa habitats; his work is our prime link to understanding the native condition of the state. His field notebooks are still in existence and will increase in value as our native vegetation is further lost. Titles of his articles are included in the bibliography.

Nothing was done with the "Twenty-five Year Plan" until 1944, when the conservation committee of the Iowa Academy of Science, chaired by Ada Hayden, professor of botany at Iowa State University, issued a report which formally recommended the plan's implementation. A report issued that same year (Conservation Committee, Ia. Acad. Sci. 1944) located 22 prairie areas suitable for preservation; this resulted in the purchase of a tract in Howard County in 1946. This 97.1 ha (240 acre) prairie, purchased with fish and game trust funds, was named Hayden Prairie, for Dr. Hayden.

During this time the conservation committee of the Iowa Academy of Science was active: Hayden and Doty (1945) stated objectives and procedures for conservation of Iowa prairies; Hayden (1946) gave a progress report on prairie preservation and recommendations on the types of undisturbed lands and soil types to preserve; Hayden (in Conservation Committee, Ia. Acad. Sci. 1944) compiled the history of the pioneer work in conservation of the Iowa Academy of Science; Aikman (1949) specified what an academy can do to further conservation, detailing the philosophy and procedures for aiding in preservation of prairie remnants. This active and useful conservation committee has since been abolished.

Management procedures also were being formulated during this period: Anderson (1936, 1947) described the development and resotration of a prairie at Iowa Lakeside Laboratory on Lake Okoboji, a project which was only recently revived; Aikman (1955) did early work with burning as a management tool; Hayden and Aikman (1949) worked out general and special management procedures for Iowa prairies; Ehrenreich and Aikman (1963) did early work on the effect of burning on seedstalk production. The influence of Dr. Hayden was important during this period; titles of her publications concerning Iowa's prairies may be found in the bibliography.

During this active period of prairie interest, several other prairies were purchased; in 1948, the 64.7 ha (160 acre) Kalsow Prairie in Pocahontas County was purchased with fish and game trust funds; in 1960, Cayler Prairie in Dickinson County and, in 1961, Sheeder Prairie in Guthrie County were purchased, both with lands and water funds.

In 1965, the Iowa legislature created the Iowa State Preserves Advisory Board, consisting of seven members, six appointed by the governor, the seventh member being the director of the State Conservation Commission, serving by virtue of his position. This board oversees the management of the areas dedicated as state preserves and is authorized to hire an ecologist to carry out the board's functions. In 1968, Hayden Prairie was formally dedicated as the first state preserve, followed by Kalsow, Sheeder and Cayler Prairies. Kalsow, Cayler and Hayden Prairies have since been designated as National Natural Landmarks. Signatures of the governor, Conservation Commission chairman, Preserves Board chairman and owner are required to dedicate an area as a state preserve. Areas thus dedicated into the state's system of preserves are given maximum protection, since removal of an area from the system or intrusion into a preserve requires these same signatures, public hearings and concurrent resolutions of both houses of the Iowa legislature.

During this period of prairie preservation, two other important events occurred. In 1955, a system of county conservation boards was created by the legislature. Iowa, a pioneer in this movement, has now established county boards in 98 of its 99 counties. This has been an importnat step in the development of conservation programs in Iowa as many natural areas, including several native prairies, have been acquired by these county boards. Ennis (1962, 1964) has given the history of the county conservation board movement in Iowa. In 1963, the Iowa chapter of the Nature Conservancy was formed, and to date has protected ten tracts of native landscape by deed, purchase or lease, with several areas in negotiation. These total over 142 ha (350 acres) and include several prairies. Burk (1973) has given the history of the Nature Conservancy in Iowa and the status of its holdings.

Since the initial purchase of the four prairie tracts, the state has purchased no additional prairies, although some newly acquired areas have included patches of prairie. The Nature Conservancy and several county conservation boards, however, have purchased several parcels of prairie. The Kossuth

County Board, in 1970, purchased the 13 ha (32 acre) Stinson Prairie and in 1972 dedicated it as a state preserve. The Webster County Board purchased the 8 ha (20 acre) Liska-Stanek prairie in 1972. About the same time, the Iowa Chapter of The Nature Conservancy acquired two prairie tracts, the 8 ha (20 acre) Williams Prairie in Johnson County, and the 44.5 ha (110 acre) Kettlehole and prairie in Dickinson County, purchased with a gift from Freda Haffner, Burlington, Iowa. In 1961, the University of Northern Iowa was given a 1.2 ha (3 acre) tract of native prairie in Butler County. In 1976, these last four areas were dedicated into the state's system of preserves, bringing the total to approximately 283 ha (700 acres) protected by preserve status. Additionally, late in 1976, the Wayne Mark family of Cedar Falls announced the gift of their 12.5 ha (31 acre) Sand Prairie to the Nature Conservancy, and the Crossman family donated a 4 ha (10 acre) prairie in Howard County to the Conservancy. Agencies or persons dedicating areas into the state preserve system retain management and ownership. Dedication provides protection from encroachment, expertise of an advisory board in developing management plans, and publication of informal brochures.

Dr. Roger Landers of Iowa State University and his students have continued to conduct research on Iowa prairies, and have been instrumental in developing management plans for them (see Brotherson 1969, Brotherson and Landers 1973, Christiansen 1969, 1972, Richards 1969, 1970). Dr. David Glenn-Lewin of Iowa State University and his students have recently completed studies on one of Iowa's prairie preserves (Glenn-Lewin 1976), and are currently conducting research which will permit quantitative comparisons of Iowa's prairies. Dr. William Platt of the University of Illinois-Chicago Circle is continuing research on the flora and fauna of Cayler Prairie (Platt 1975, Platt and Blakley 1973).

Planning for prairie preservation in Iowa is now underway. The State Preserves Advisory Board is developing a comprehensive plan which includes the location and acquisition of remnant tracts, using both Hayden's (1946) list based on factors of climate and topography, and guidelines by Reicken (1946) which used soil types as criteria for preservation. The Board is attempting to locate prairie areas on state lands, to establish a registry, and suggest management to protect them from incompatible use or accidental destruction. The Nature Conservancy is developing a comprehensive plan which will address the issue of prairie preservation. One tract of native prairie of 64.7 ha (160 acres) and one of approximately 40.5 ha (100 acres), both in private ownership, have been located in northwest Iowa and initial negotiations have occurred. Additionally, at least five virgin tracts of approximately 10 ha (25 acres) each are being maintained by private citizens through personal pride. Sizeable tracts are being sought in the loess hills of western Iowa. It would be unfortunate if any further destruction of prairie occurred in Iowa, which at one time epitomized the tall grass prairie.

LITERATURE CITED AND BIBLIOGRAPHY

Aikman, J. M. 1949. What an academy can do to promote the Conservation of natural resources. Proc. Iowa Acad. Sci. 56:29-36.

Aikman, J. M. 1955. Burning in the management of prairie in Iowa. Proc. Iowa Acad. Sci. 62:53-62.

Anderson, W. A. 1936. Progress in the regeneration of the prairie at the Iowa Lakeside Laboratory. Proc. Iowa Acad. Sci. 43:87-93.

Anderson, W. A. 1947. Development of prairie at Iowa Lakeside Laboratory. Amer. Midl. Nat. 36:439-455.

Brotherson, Jack D. 1969. Species composition, distribution and phytosociology of Kalsow Prairie, a mesic tall-grass prairie in Iowa. Ph.D. Dissertation. Iowa State Univ.

Brotherson, Jack D., and Roger Q. Landers. 1973. Species patterns in relation to soil moisture gradients in Kalsow Prairie. Third Midwest Prairie Conf., Proc. Manhattan, Kansas. p. 62.

Burk, Myrle. 1973. Natural areas owned by the Iowa Chapter of the Nature Conservancy. Proc. Iowa Acad. Sci. 80:175-177.

Christiansen, Paul A. 1969. A management master-plan for Hayden Prairie, Howard County, Iowa. Iowa State Preserves Advisory Board. 77 pgs.

Christiansen, Paul A. 1972. Management on Hayden Prairie: Past, present and future. In: J. H. Zimmerman, ed. Proc. Second Midwest Prairie Conf. p. 25-29.

Christiansen, Paul A., and R. Q. Landers. 1966. Notes of prairie species in Iowa. I. Germination and establishment of several species. Proc. Iowa Acad. Sci. 73:51-59.

Conservation Committee, Iowa Acad. Sci. 1944. Present status and outlook of conservation in Iowa. Proc. Iowa Acad. Sci. 51:39-96.

Crane, Jacob L., and G. W. Olcott. 1933. Report on the Iowa Twenty-five Year Conservation Plan. Iowa Board of Conservation, and Iowa Fish and Game Commission.

Dick-Peddie, W. A. 1953. Primeval forest types in Iowa. Proc. Iowa Acad. Sci. 60:112-116.

Ehrenreich, J. H. 1957. Management practices for maintenance of native prairies in Iowa. Ph.D. Dissertation. Iowa State Univ.

Ehrenreich, J. H., and J. M. Aikman. 1963. An ecological study of the effects of certain management practices on native prairies in Iowa. Ecol. Monogr. 33:113-130.

Ennis, J. Harold. 1962. The county conservation program in Iowa. Proc. Iowa Acad. Sci. 69:218-223.

Ennis, J. Harold. 1964. Some matters of concern in the county conservation program in Iowa, with special reference to land use. Proc. Iowa Acad. Sci. 71:212-216.

Glenn-Lewin, David C. 1976. The vegetation of Stinson Prairie, Kossuth County, Iowa. Proc. Iowa Acad. Sci. 83:88-92.

Hayden, Ada. 1918. Notes on the floristic features of a prairie province in central Iowa. Proc. Iowa Acad. Sci. 25:369-389.

Hayden, Ada. 1919. The ecologic foliar anatomy of some plants of a prairie province in central Iowa. Amer. J. Bot. 6:69-85.

Hayden, Ada. 1919. The ecological subterranean anatomy of some plants of a prairie province in central Iowa. Amer. J. Bot. 6:87-105.

Hayden, Ada. 1945. The selection of prairie areas in Iowa which should be preserved. Proc. Iowa Acad. Sci. 52:125-148.

Hayden, Ada. 1946. A progress report on the preservation of prairie. Proc. Iowa Acad. Sci. 53:45-82.

Hayden, Ada. 1947. The value of roadside and small tracts of prairie in Iowa as preserves. Proc. Iowa Acad. Sci. 54:28-31.

Hayden, Ada. 1948. The Iowa Lakeside Laboratory - A prairieless field laboratory. Proc. Iowa Acad. Sci. 55:163-170.

Hayden, Ada, and J. M. Aikman. 1949. Considerations involved in the management of prairie preserves. Proc. Iowa Acad. Sci. 56:133-142.

Hayden, Ada, and H. S. Doty. 1945. State parks and preserves. Proc. Iowa Acad. Sci. 52:32-34.

Platt, William J. 1975. The vertebrate fauna of Cayler Preserve, Dickinson County, Iowa. Proc. Iowa Acad. Sci. 82:106-108.

Platt, William J., and Nigel R. Blakley. 1973. Short-term effects of shrew predation upon invertebrate prey sets in prairie ecosystems. Proc. Iowa Acad. Sci. 80:60-66.

Reicken, F. F. 1946. Supplementary recommendations: Preservations of undisturbed land areas in Iowa. Proc. Iowa Acad. Sci. 53:47-49.

Richards, Mary S. 1969. Observations on responses of prairie vegetation to an April fire in central Iowa. M.S. thesis, Iowa State Univ.

Richards, Mary S. 1970. Report on the vegetation of Kalsow Prairie. Iowa State Preserves Advisory Bd. 50 p.

Shimek, Bohumil. 1910. Prairie openings in the forest. Proc. Iowa Acad. Sci. 17:16-19.

Shimek, Bohumil. 1910. Botanical report. The prairies. In: Geology of Harrison and Monona Counties. Annual Report, Iowa Geol. Sur. 20:426-483.

Shimek, Bohumil. 1911. An artificial prairie. Univ. Iowa Lab. Nat. Hist. Bull. 6:35-41.

Shimek, Bohumil. 1911. The prairies. Univ. Iowa Lab. Nat. Hist. Bull. 6:169-240.

Shimek, Bohumil. 1924. The prairie of the Mississippi River bluffs. Proc. Iowa Acad. Sci. 31:205-212.

Shimek, Bohumil. 1925. The persistence of the prairie. Univ. Iowa Stud. Nat. Hist. 11:3-24.

Shimek, Bohumil. 1927. The prairies. Wild Flower 4:6-7.

Shimek, Bohumil. 1928. The prairies again. Science 68:321-323.

Shimek, Bohumil. 1948. The plant geography of Iowa. (H. S. Conard, ed.) Univ. Iowa Stud. Nat. Hist. 18:1-178.

OHIO PRAIRIES AND THE OHIO PRAIRIE SURVEY PROJECT

Ralph E. Ramey
Director, Glen Helen
Antioch College
Yellow Springs, Ohio 45387

and

K. Roger Troutman
Naturalist, Kingwood Center
Mansfield, Ohio 44906

ORIGINAL PRAIRIE

In June 1810, the American naturalist Thomas Nuttall traveled, on foot, west from the mouth of the Huron River on Lake Erie's south shore a distance of "about 10 miles toward Sandusky Bay." He wrote "The road crosses an extensive prairie, this commences near Huron; and it is here from 8 to 12 miles wide, but its extent, if I am correctly informed, is astonishing; it is said there is a continuation of prairies from this place to the Scioto River" (Graustein 1950).

Five years later, Samuel Brown, who walked from Maumee Bay (Toledo) to the mouth of the Portage River (Port Clinton), gave another eyewitness account. He estimated the "Great Meadow" contained 200,000 acres and was 10 miles wide in places. In October he found the grass almost inpenetrable on foot, "higher than our heads and as thick as a mat, confined together by a species of pea vine" (Brown 1815).

Ohio, in the years immediately after statehood, still included vast expanses of prairie. By 1805, the bison, which were once plentiful in the open country of the northwest part of the state, had already vanished, and by 1822, the elk were no more to be seen (Slocum 1905). Gray wolves were reported to be disappearing from the region by 1878, and by 1879, Wheaton (1879) reported the prairie hen as a rare resident of northwest and central Ohio, although Potter (1870) had reported seeing over 500 chickens near Summit and Jackson streets in Toledo only forty years earlier.

When Sears (1926) published the first map of the original prairies of Ohio, he had to supplement field work with a search of the original land surveys because nearly all of the hundreds of thousands of the prairie acres in the glaciated central and northwestern parts of the state had disappeared. These were the wet prairies that could be found in poorly drained former lake bottoms of the northwestern part of the state, and in association with fens or morainal features elsewhere, and also the mesic prairies that had persisted on shallow till over Silurian dolomities and shaley limestones in the west central part of the state. In the Congress and Firelands of northwestern Ohio, ditches on the quarter section lines had drained away the water that had limited tree development since the invasion of the area by grasses during the Xerothermic Period (Transeau 1935, Ogden 1966). In west central Ohio, the advent of the sodbusting plow made possible the conversion of prairies to fields of grain. In unglaciated southern Ohio, the xeric prairies of bluff tops and shaley hillsides above the Silurian rocks were less accessible and therefore remained little disturbed. Braun's (1928) study of "The Vegetation of the Mineral Springs Region of Adams County, Ohio" describes these specialized habitats where prairies may have existed since before the Pleistocene Period.

In 1935, Transeau published his well-known "Prairie Peninsula" paper and maps. Jones (1944) adapted Transeau's map for a paper on Ohio prairies, and in 1950 Transeau further modified it for use by botany classes at The Ohio State University. Gordon (1966), in his map of the original vegetation of Ohio at the time of settlement based on early land patent descriptions, showed over 300 areas of prairie.

OHIO PRAIRIE RELICTS

By the 1950's, only a few patches of native Ohio prairie were known to remain, and what protection was being afforded them was mostly accidental or serendipitous. In 1941, the Department of Ohio Division of Conservation began purchasing land near Castalia in Erie County, northern Ohio, for the Resthaven Wildlife Area, Ohio's first Pitman-Robertson Act acquisition. The area had been quarried for marl, and the water-filled quarry pits provided fine waterfowl nesting habitat. Although many acres of prairie remain today, much of the best prairie in the unquarried area was plowed and planted to corn to attract wildlife. The land between the pits that was in prairie at the time of purchase was allowed to grow up to cottonwood trees.

In 1952, the Division of Wildlife of the then new Ohio Department of Natural Resources began acquisition of the Killdeer Plains Wildlife Area in Wyandot County, north central Ohio. This 30,000-acre area of wet prairie is the last place where prairie chickens were seen in Ohio. They nested there in 1934 and 1935 following reintroduction in 1933. To date, just over 8,000 acres have been acquired. It is interesting that the preliminary project statement for the acquisition of this area included as a planned wildlife restoration development "The restoration of a small population of prairie chickens." Unfortunately, the Division of Wildlife has never carried through on this project. From a prairie preservation point-of-view, the management of the area has been variously good and bad. Soon after it was purchased, dikes were built to allow permanent flooding of some of the area for Canada goose production, and as recently as 1975, some previously idle field usually inhabited by short-eared owls during the winter were plowed and planted to corn to attract more waterfowl. On the other hand, the value of preserving some original prairie was recognized early, and, in fact, a sizable area of previously disturbed land was seeded with prairie species in the mid-1950's. In 1970, Kim Heller, a naturalist and Division of Wildlife hunting and fishing instructor living on the area, wrote a booklet on "The Prairie Plants of Killdeer Plains" and established an automobile "Self-Guided Tour" of the Area (Ohio Dept. Nat. Res. 1970a, 1970b).

In 1941, the Ohio Department of Public Works purchased 98 acres of arbor-vitae bog in Champaign County, to be managed by the Ohio Archeological and Historical Society (now The Ohio Historical Society). Called Cedar Swamp Nature Sanctuary at the time, it was later changed to Cedar Bog Nature Preserve (1967). It is technically a fen and is the only remaining remnant of a reported 7,000-acre fen that once occupied the Mad River valley north of Springfield. In addition to the stands of arbor-vitae and the bog meadow and marl meadow associations, for which it is well known, the preserve contains a substantial wet prairie element (Friedrick 1974). In 1968 it was doubled in size by a purchase assisted by The Nature Conservancy, and it is now being further expanded to include additional buffer area and bog meadow. A management plan is now in preparation that should help to maintain the unique diversity of habitats and species found there.

The first project of the Ohio Chapter of The Nature Conservancy after it was organized in 1958 was the acquisition of 53 acres of xeric prairie near Lynx, in Adams County, southern Ohio. This area is now called the "Lynx Prairie - E. Lucy Braun Preserve," and is located within a few miles of four other areas which contain small xeric prairies: the 465-acre "Buzzardroost Rock - Christian and Emma Goetz Preserve," the 645-acre "Wilderness - Charles A. Eulett Preserve," the 93-acre "Red-Rock - Earl F. Farnau Preserve," and the 50-acre "Abner Hollow - M. E. Brockschlago Preserve." All of these preserves are near the edge of the Appalachian Plateau just east of Ohio Brush Creek in the unglaciated part of the state. They contain the finest examples of the xeric prairies of the area. All were acquired by The Nature Conservancy and are now managed by the Cincinnati Museum of Natural History.

Also lying within the unglaciated southeastern portion of Ohio is an area in Athens County called "Buffalo Beats." Less than one acre in size, it is situated in an opening in mixed oak forest on a site where the soils are derived from a calcareous clay. The soils of the surrounding forest are acid, being derived from sandstone and shale. It is located within the Wayne National Forest, and the forest manager is aware of its scientific value, although it is not listed in the U.S. Forest Service list of "Research Scientific Areas." Wistendahl (1975) described this unusual area in detail.

After the Ohio Natural Areas Act was passed in 1970, one of the first purchases made by the Department of Natural Resources under the new law was a 23-acre xeric prairie on a badly eroded calcareous shale hillside adjacent to Adams Lake State Park, near West Union about eight miles west of the Lynx Prairie area. It contains fine examples of ant mounds and a good stand of prairie dock. The species is largely absent in the Lynx area prairies except in a few places where there is seepage.

In 1972, the Toledo Naturalist Association, in cooperation with The Nature Conservancy, acquired a 26-acre tract of wet and mesic prairie, along Schwamberger Road west of Toledo, that contains a good mixture of prairie plant species growing on a fossil lake beach or sandbar. It will soon be turned over to the State so that the Department of Natural Resources can use it as a gift to obtain matching Federal Funds for enlarging the area. A few miles away, the Department of Natural Resources, in cooperation with The Nature Conservancy, has acquired over a hundred acres of the 200-acre tract known as Irwin Prairie. This wet prairie, which has been intensively studied by Easterly (1972) and Tryon and Easterly (1975), has defied development becuase of poor drainage.

In 1974, Natural Areas Administrator Richard Mosely (now chief of the Division of Natural Areas and Preserves, Ohio Department of Natural Resources) prepared a list of "Ohio Prairies Presently Being Preserved" for the North American Prairie Inventory (Moseley 1974). The above areas, plus two of questionable value, were all that he could report. Of the thousands of acres of prairie in Ohio at the time of settlement, only a few hundred acres remained.

Field botanists and naturalists were becoming concerned about the disappearance of native grassland from Ohio. In order to be able to show Ohio's citizens this element of the native vegetation, it appeared that new prairies might have to be planted. The Aullwood Audubon Center near Dayton began such a project in 1959, and this effort has met with good success. Other nature centers, garden centers and arboretums have since started similar projects.

OHIO PRAIRIE SURVEY PROJECT

In October 1971, a group of Ohio botanists and naturalists concerned about prairie preservation, establishment, and management gathered at Aullwood Audubon Center for the first Ohio Prairie Conference. Convened by Dr. T. R. Fisher of Bowling Green State University, it was the spawning bed for what is today known as the Ohio Prairie Survey Project of the Ohio Biological Survey. At that meeting, Roger Troutman of Kingwood Center presented a written proposal calling for the establishment of an on-going organization of persons interested in prairies. Proposed purposes for such a group included the conducting of a census of prairie remnants, preservation of remnants, establishment of an information clearing house, and the establishment of a seed exchange. Though there was general agreement that such an organization would be useful, no action was taken on Troutman's proposal at that time.

Out of the discussion on fire ecology at that meeting, however, did come an invitaiton from Joseph Bachant, then a Division of Wildlife game farm Research Project leader, to visit wildlife areas where controlled burning was used to maintain grassland. In August 1972, a number of persons interested in prairie and prairie management toured the Resthaven Wildlife Area where they observed the effect of prescribed burning.

It was not until March 1974, that persons interested in Ohio prairies once more gathered on a formal basis. This time it was at the invitation of Michael Sayers, a helicopter pilot for the Ohio Department of Natural Resources, who had gotten "turned on" to prairies. At one point he was so excited about Ohio prairies that he proposed flying across western Ohio in his "chopper" to scatter Big Bluestem seeds wherever there was still idle land that was thought to have once been prairie. The agenda for the meeting was informal, with the invitation reading "the meeting will discuss present and future status of

Ohio's prairies and means by which they may be established. Anybody desiring to present pertinent information may do so." Troutman's proposal was once again considered, and Dr. Charles King, executive director of the Ohio Biological Survey (an inter-institutional research organization based at The Ohio State University), offered his organization as the logical home for a prairie committee. A Raptor Survey Project was already functioning within the Survey, and King was certain the Executive Committee would approve the establishment of a similar project on prairies. On April 25, 1974, the OBS Executive Committee authorized the creation of the Ohio Prairie Survey Project Committee and charged it "to identify areas of existing prairie and prairie species." A steering committee was formed, and a date was set for an organizational meeting. This meeting took place at the Aullwood Audubon Center in June 1974. Steve Bass of the Aullwood Audubon staff chaired the meeting, having previously agreed to serve as committee chairman. Roger Troutman agreed to serve as secretary. First, an acceptable definition was agreed upon for "prairie." Then, following a discussion of the "ecotype issue," plans were made to undertake statewide prairie inventory. These plans called for the enlisting of qualified local persons to assist in the field work under the direction of county coordinators. A "packet committee" agreed to prepare appropriate handout material for volunteers and a list of "indicator species" was drawn up. Those species chosen are all conspicuous, easily identified mid- and late-summer bloomers on wet-to-mesic sites. They are: big bluestem, Indiangrass, gray-headed coneflower, prairie dock, saw-toothed sunflower, and the blazing stars. The next meeting was set for August 24, 1974, at Killdeer Plains Wildlife Area, with a morning meeting to be followed by a field trip to the wet prairies of the region.

At the August meeting, a paper entitled "Ohio is a State with Prairie - What is an Ohio Prairie" by committee member Dr. Joe Laufersweiler from the University of Dayton was distributed. Joseph Steiger, a Soil Conservation Service agronomist on the Committee, distributed papers he had prepared on "Prairie Soils" and "Tips on Contacting Residents in Rural Areas." Papers on "Prairie Adaptations" and "Prairie Fire Effects" from the University of Wisconsin Arboretum, a copy of "The Prairie Plants of Killdeer Plains", and a supply of "Ohio Prairie Site Survey" inventory forms with instructions, completed "The Prairie Packet." Volunteers were solicited to become county coordinators, and Roger Troutman agreed to assume the chairmanship of the committee because Steve Bass was leaving the state.

In addition to conducting the prairie site survey, the committee is working to inform the general public of the existance and value of prairies, advising land owners of the existance of prairie or prairie species on their property, and advising or assisting land owners with the management and preservation of patches of prairie.

The Prairie Survey Project committee next came together in June 1975 at Kingwood Center, Mansfield. There was a discussion of the state Natural Heritage Program being planned by the Division of Natural Areas and Preserves of the Ohio Department of Natural Resources, and consideration was given to making prairie survey data usable for that natural area inventory. Troutman showed a printout of a computerized prairie site report that he had developed, but it was decided to defer action on computerizing data until the Natural Heritage Program got underway. Jay Leibovitz agreed to circulate a questionnaire among committee members to ascertain their specific areas of expertise.

In September the committee met in Yellow Springs, Ohio, at Antioch College's Glen Helen. Troutman offered a proposed system of classification of prairies and local ecotypes. It would classify prairies as I) natural, II) invader, III) re-established, or IV) established, and on the basis of distance to seed sources as A) "local ecotype," B through E) one of four levels of "ark prairies," or F) "synoptic prairie." A seed source rating of 1) seed preserve, or 2) seed sources, would complete the classification code. Thus most railroad prairies would be II-A-2, that is "invader prairies with sources less than 10 miles distant and available as a seed source" (Troutman 1975). Members were asked to consider this proposal for discussion at a later date.

Plans were made at this meeting for production of a slide set with a script on Ohio prairies and a portable display. Limited funds were available from OBS for these, and from a project brochure. Probably the most significant action of this meeting, however, was the decision to seek additional money from the OBS to fund a full-time person during the summer of 1976 to coordinate and expedite the project.

Committee members, who by then numbered more than 80, received an up-date on the progress of the various phases of the project at a meeting at Sharon Woods Metropolitan Park in Columbus, in January 1976. They next met at Miami University at Oxford, Ohio, in April 1976, where it was announced that $1500 would be available to hire a person for the summer. In addition, three of the Ohio Biological Survey's annual research grants announced at that meeting went to prairie-related research projects. A new brochure about the project was available for the first time, and at that meeting Dick Mills from Aullwood Audubon Center announced the completion of a slide-tape program about Ohio prairies and the survey.

In mid-July 1976, Mr. Allison Cusick, an instructor in the Biological Sciences Department at Kent State University, was hired as the first paid coordinator.

The question regularly arises as to how one goes about locating prairies and prairie plants. The obvious place to start is with the existing literature. Vegetation maps such as "The Natural Vegetation of Ohio at the Time of the Earliest Land Surveys" (Gordon 1966), and the accompanying text, "The Natural Vegetation of Ohio in Pioneer Days" (Gordon 1969), are basic tools. Three recent OBS publications, "A Guide to the Literature on Ohio's Natural Areas" (Elfner et al 1973), "Bibliography of Theses and Dissertations on Ohio Floristics and Vegetation" (Roberts and Stuckey 1974), and "The Natural Areas Project - A Summary of Data to Date" (Herrick 1974), are most helpful, as are many of the early OBS bulletins. Having transferred such data to local maps, the field work commences. Railroad and utility rights-of-way, cemeterys, ditches, and streambanks are good places to start, although the clean cultivation practices of today make the return low. Sometimes place names give clues to possible areas of former prairies, but more often than not drag lines and herbicides have so altered the land that not a trace of prairie will be visible. Every now and then, however, the search hits "pay dirt" and the extra mile walked will yield a gem of a prairie patch in some forgotten corner of a "farmer's back forty."

A form is then completed on another prairie site for what should eventually be the most complete survey ever made of the remnants of Ohio's original prairies.

The work is already paying dividends as new sources of seed have been discovered for use in establishing prairies at nature centers and arboretums, and some local land owners have agreed to withhold spray and provide protection to the prairie remnants. In addition, new sites have been identified which may have some potential for preservation by the Ohio Division of Natural Areas and Preserves, local park districts, or The Nature Conservancy.

LITERATURE CITED

Braun, E. L. 1928. The vegetation of Mineral Springs region of Adams County, Ohio. Bull. 15. Bull. Ohio Biol. Sur. 5:383-517.

Brown, Samuel. 1815. Views of the campaigns of the Northwestern Army, etc. William G. Murphy, Philadelphia.

Easterly, N. W. 1972. The Compositae of the oak openings. Ohio. J. Sci. 72:11-21.

Elfner, L. E., R. L. Stuckey, and R. W. Melvin. 1973. A guide to the literature of Ohio's natural areas. Ohio. Biol. Sur. Information Circular No. 3. Columbus.

Frederick, C. M. 1974. A natural history study of the vascular flora of Cedar Bog, Champaign County, Ohio. Ohio. J. Sci. 72:65-116.

Gordon, R. B. 1966. Natural vegetation map of Ohio at the time of the earliest land surveys. Ohio Biol. Sur. Columbus, Ohio.

Gordon, R. B. 1969. The natural vegetation of Ohio in pioneer days. Ohio. Biol. Surv. Bull, New Series 3:XI-113.

Graustein, J. E., ed. 1950/51. Nuttall's travels in the old northwest, an unpublished 1810 diary. Chronica Botanica Company, Waltham, Mass.

Herrick, J. A. 1974. The Natural Areas Project - A summary of data to date. Ohio Biol. Sur. Information Circular No. 1. Columbus.

Jones, C. H. 1944. Studies in Ohio floristics. III. Vegetation of Ohio. Bull. Torrey Bot. Club 71:536-548.

Moseley, R. E., Jr. 1974. Ohio prairies presently being preserved. Internal paper, Ohio Dept. Nat. Res., Columbus.

Ogden, J. G. 1966. Forest history of Ohio. I. Radiocarbon dates and pollen stratigraphy of Silver Lake, Logan County, Ohio. Ohio J. Sci. 66:387-400.

Ohio Department of Natural Resources. 1970a. Prairie plants of Killdeer Plains Wildlife Area. Div. Wildl. Publ., Columbus, Ohio.

Ohio Department of Natural Resources. 1970b. Self-guided tour of Killdeer Plains Wildlife Area. Div. Wildl. Publ., Columbus, Ohio.

Potter, E. E. 1870. Small game of the Maumee Valley. Toledo Commerical, March 19.

Roberts, M. L., and R. L. Stuckey. 1974. Bibliography of theses and dissertations on Ohio floristics and vegetation in Ohio colleges and universities. Ohio. Biol. Surv. Information Circular No. 7. Columbus.

Sears, Paul B. 1926. The natural vegetation of Ohio. II: The prairies. Ohio J. Sci. 26:128-146.

Slocum, Charles E. 1905. History of the Maumee River Basin. Published by the author, Defiance, Ohio.

Transeau, E. N. 1935. The prairie peninsula. Ecology 16:423-437.

Troutman, K. R. 1975. Classification of prairies and local ecotypes. Paper prepared for Ohio Prairie Survey Project, Ohio. Biol. Sur., Columbus.

Tryon, C. A., and W. N. Easterly. 1975. Plant communities of the Irwin Prairie and adjacent wooded areas. Castanea 40:201-213.

Wheaton, J. M. 1879. Report on the birds of Ohio. Ohio Geol. Sur., Columbus.

Wistendahl, W. A. 1975. Buffalo Beats, a relict prairie within a southeastern Ohio forest. Bull. Torrey Bot. Club 102:178-186.

PHYSIOGRAPHIC RESOURCES OF ALTERNATIVE STUDY AREAS OF PROPOSED PRAIRIE NATIONAL PARK

Robert Page
Department of Landscape Architecture
Kansas State University
Manhattan, Kansas 66506

ABSTRACT

Excerpts are presented from the recent preliminary environmental assessment of alternative areas of the proposed Prairie National Park prepared by the National Park Service.

INTRODUCTION

This paper deals primarily with portions of the Preliminary Environment Assessment of Alternative Study Areas of the Proposed Prairie National Park in Kansas and Oklahoma prepared by the Denver Service Center of the National Park Service, Department of Interior, and issued in October, 1975.

In November 1974 five of our students (Department of Landscape Architecture, Kansas State University) Larry Walling, Roger Denton, Larry Monahan, Terry Smythe, and Dan McClelland, began a work-study program to assist the National Park Service in preparation of these reports. The assessment is in two volumes, the smaller one dealing with the background of the project and the larger one containing appendixes A through N. These reports are in scarce supply; however, copies should be found in major university libraries in the region.

A. W. Kuchler's maps and reports tell us that the potential range of the bluestem prairie occurs in the eastern portions of Kansas, Nebraska, North and South Dakota, northwestern Iowa, and southwestern Minnesota. In 1975 The Nature Conservancy report on American Prairie Inventory tells us that about 6,400 acres (2590 ha) of prairie remnants exist in North Dakota. Of the ten bluestem prairie areas within the state, there are three larger than 1,000 acres (404.7 ha). South Dakota has 49 bluestem prairies, three of which are larger than 1,000 acres. Nebraska has 13 bluestem prairies, one of which is over 1,000 acres. It is estimated that Kansas has over 900,000 acres (364,230 ha) of bluestem prairie. Of the ten sites now preserved, six are over 1,000 acres. A recent gift from The Nature Conservancy has preserved approximately 8,000 acres (3,238 ha) of the Konza Prairie near Manhattan, Kansas.

There are three land acquisition and management concepts that are suggested: (1) Preservation of a large parcel of publicly owned land. (2) Preservation of a publicly owned core parcel with use controls on adjacent land. (3) Acquisition of scenic easements with publicly owned land limited to small parcels for public facilities.

Studies in 1958 had identified 24 potential prairie park sites in six states, but in 1959 the number of sites was reduced to 13. The search was narrowed to seven sites in the Flint Hills of Kansas and Oklahoma in 1974. These seven sites were measured against six criteria as determined by the National Park Service: (1) Must have a representative tallgrass ecosystem, (2) Must be a relatively stable community, (3) Must have scenic attributes typical of the prairie, (4) Must be a manageable unit with watershed control, (5) Must be adaptable to diverse opportunities, (6) Must be relatively free from physical disturbances and distractions.

DESCRIPTION OF THE SEVEN SITES

Pottawatomie is a 86,000 acre (34,804 ha) study site located immediately north of Manhattan, Kansas. It is bisected by State Highway 13 and is bound on the west by Tuttle Creek Reservoir. The area was rejected as major portions of the site were not in a stable prairie community. It has poor watershed control and has serious intrusions and distractions such as the reservoir, dam, highway, and Manhattan and has a limited area of highly desirable prairie.

Wabaunsee east is a 93,000 acre (31,637 ha) study just south of Interstate 70. It could not qualify as a stable prairie community. The area did not have manageable watersheds, had major intrusions of transmission lines and relay stations, and had limited areas of highly desirable prairie. This site was rejected.

Wabaunsee west has a large area of highly desirable prairie and fully meets most criteria.

Chase north is a 76,000 acre (30,757 ha) study area adjacent to Interstate 35. The site was not found to be representative of a tallgrass ecosystem. The area does not possess typical scenic prairie attributes, is located in unmanageable watersheds, and is not adaptable to diverse opportunities and activities. It was rejected for further study as it has a limited area of highly desirable prairie.

Chase south is a 100,000 acre (40,470 ha) study area just south of Interstate 35. It has sizable areas of highly desirable prairie and meets all criteria except a lack of intrusions and disturbance. However, it was recommended for further study.

Elk is a 100,000 acre (40,470 ha) study area that is bisected by a transmission line, is located in unmanageable watersheds, the prairie community is not stable, is low in scenic attributes, and has only isolated areas of highly desirable prairie which would not be adaptable to park activities.

Osage is a 93,000 acre (37,637 ha) study area primarily in northern Oklahoma. It has a large area of highly desirable prairie and meets all criteria for further study.

An evaluation matrix was used to plot 30 environmental characteristics and features in reviewing these seven sites. A matrix summary was made and three sites were recommended for further study.

The Wabaunsee west site has the greatest elevation extreme of the three study areas with a 500-foot (152.5 m) difference in elevation. The entire area drains to the north with three prominent north, south ridges and valleys. Slopes of over 25% occur on a sizeable area in the east portion of the site. The magnitude of visual disturbance was mapped indicating areas where towns and transmission lines intrude into the site. Major intrusions are from two adjacent small towns. However, a large portion of the interior is free from visual intrusions.

The Chase area lies roughly in the middle of the Flint Hills and encompasses the Flint Hills Ridge, the highest in the region. This gentle ridge runs east and west through the area separating the two principal protected watersheds of the site. Elevation varies about 400 feet (122 m) within the area. The Chase site differs from Wabaunsee in that it has broad upland ridges while the Wabaunsee site has an even pattern of ridges and valleys. Major visual disturbances are limited to the northwest edge coming primarily from towns and Interstate Highway 35 and a transmission tower. Limited visual disturbance is on the southeast coming from reservoir and oil fields.

The greatest portion of the Osage site is rolling topography contrasted with steeper stream sides and a higher plateau and steep escarpments to the west. There are limited areas of visual disturbances within the site coming from small towns to the north and west.

The report ends with a plea for a regional management concept. According to the report, intrusions have significantly modified the character of the grassland in the Flint Hills. Without a unified effort beginning at the county and state level these intrusions will continue to significantly alter the character of the prairie. It is critical that regional management be considered now as this region is truly unique in the North American landscape and is a resource of national significance (preserved today through past stewardship of several generations). The report further recommends that regardless of the disposition of a Prairie National Park, consideration be given to the creation of a Flint Hills Agricultural Reserve patterned after the British National Park concept, with lands retained largely in private ownership assuring maintenance of traditional landscapes and ways of life in this rich and varied region.

Students in the Department of Landscape Architecture at Kansas State University are currently preparing feasibility plans for a prairie park on the Chase and Wabaunsee sites. An alternate study is also being prepared using the concept of a prairie parkway with smaller public use nodes. This concept is easier to implement due to reduced land acquisition and is probably better suited to land use patterns in the region.

THE HOOSIER PRAIRIE STORY--A POLITICAL ODYSSEY

Irene S. Herlocker
Chairman, Hoosier Prairie Committee
8528 Schreiber Drive
Munster, Indiana 46321

ABSTRACT

The effort to preserve the Hoosier Prairie began in 1969, when we discovered that a tract of about 300 acres (121 ha) in Lake County was the last landscape prairie in Indiana. An account is given of how a small group, with the vital help of many individuals and organizations, gained support at local, state, and federal levels. The Hoosier Prairie was designated as a National Natural Landmark in 1974. In 1975 the State of Indiana budgeted $1,000,000 for the Prairie, and it was also included within the authorized boundaries of the expanded Indiana Dunes National Lakeshore.

THE HOOSIER PRAIRIE STORY

Trying to summarize ten years of my life in twenty minutes is one of the biggest challenges I've ever had. The biggest was trying to condense my testimony before Congressional committees to three minutes.

The Hoosier Prairie is in Lake County, Indiana, about 35 miles (56 km) southeast of Chicago. It was designated as a National Natural Landmark in 1974. The Department of the Interior news release stated: "This 330-acre (134 ha) site is the last large tract of prairie remaining near the eastern margin of the 'Prairie Peninsula.' It contains a great diversity of community types and almost 300 plant species have been identified, including many rare species." I'll add that it ranges from cattail marsh to oak savanna.

My part of the Hoosier Prairie story began on May 23, 1967, when a neighbor with whom I used to go bird watching knocked on my door. Her husband was being transferred to Texas and she was leaving, so for the first time she offered to take me to her secret place which she called the "Griffith dump." She was very interested in wildflowers; I didn't know anything about them. I was over forty before I became a bird watcher, and this was even later. I tell my husband I was a late bloomer like the prairie flowers. Well, we went there on May 23. You know the prairie in late May. I was stunned. I couldn't believe there was something so beautiful only ten minutes from my home, and I'd lived within ten miles of this area all my life. The ground was covered with flowers--bird's foot violets, bluets, blue-eyed grass, yellow star grass, shooting stars .... I won't list them all--it would take all of my time. I didn't know anything about prairies then and thought they were long gone. I started learning to identify the flowers and kept going back. I began to think it was a prairie remnant, but it was almost two years before I found anyone who could confirm that.

In February, 1969, at an Audubon meeting in Illinois, I heard Paul Strand talking about areas in the Indiana Dunes that should have been preserved. I asked him after the meeting if he knew anything about an area near Kennedy and Main in Griffith, Highland, and Schererville. He jumped about a foot and said, "Oh, yes, that's the Griffith prairie! It's very valuable, it should be preserved, but it takes a lot of work." He referred me to Floyd Swink and Ray Schulenberg at the Morton Arboretum. I called Floyd Swink, who confirmed its value but said, "Keep it quiet, keep it quiet, or the price will go up." He referred me to Dr. William Beecher, Director of the Chicago Academy of Sciences, and to the Open Lands Project in Chicago. They confirmed its value but also said, "Keep it quiet." They were trying to raise money to save Goose Lake Prairie at that time. Open Lands couldn't help but referred me to The Nature Conservancy, and TNC has been involved ever since then.

I had raved about the prairie to my friends since I had first seen it and they thought I was some kind of a nut, but finally I could go to them and say, "This area <u>is</u> something special!" A friend brought over a reprint from the February, 1969, <u>Outdoor Indiana</u> that she had just received. It was an article about Indiana's new program for nature preserves, by William Barnes, Director of the Division of Nature Preserves. It told of the study being made by Dr. Alton A. Lindsey of Purdue University, Director of the Indiana Natural Areas Survey, under a Ford Foundation grant, which would assign priority ratings to natural areas. I wrote to Mr. Barnes and Dr. Lindsey asking if they knew of the existence of this prairie in Lake County. About three days later I got a telephone call from Mr. Barnes. He and Dr. Lindsey had just visited the prairie and they wanted to see me. They drove over, and that's when I learned that as far as they knew, this was the last landscape prairie in Indiana! They had not known about it before.

So there we are, with the last prairie in Indiana, in the Calumet region which is known for its steel mills and oil refineries. You may remember driving through that hazy cloud on Interstate 80. How do you save over 300 acres in Lake county, which at that time did not even have a county park? We were really under pressure, because the prairie had covered about 400 acres (162 ha) when I first saw it, and 73 acres (29.5 ha) had been sold for an oil storage tank farm. We saw almost a fourth of the prairie destroyed. I started exploring the possibilities and talking to a lot of people. The county didn't have the money--its park department was just getting started. The Indiana Division of Nature Preserves had been established the year before, and it had no money. The Nature Conservancy could not help at that time. I called my Congressman, Ray Madden. He said, "Get the support of the Izaak Walton League and the Save the Dunes Council and then talk to me." I went to the Save the Dunes Council, of which I was a member. The Indiana Dunes National Lakeshore had been established in 1966, but land acquisition had not started, so there was nothing they could do at that time. Someone in the Izaak Walton League said he would try to get a resolution passed at the IWL state convention, if I would get a letter of support and some documentation to him, so I tried to find someone who knew the plants. I was referred to Dr. Robert Betz of Northeastern Illinois University, with the comment: "He's really a nut about prairies!" Certainly all of you who know him know that he'll go anywhere to save a prairie. Within a few days he went out there and sent me the first plant list.

Dr. F. C. Richardson of Indiana University Northwest visited the prairie with me. I also talked with Dr. Kenneth Wilson of Purdue University Calumet Campus, and Norman Tuffort, Director of the Northwestern Indiana Regional Planning Commission--just about anybody and everybody that I got close to.

But, we couldn't get a handle on it. Nobody could figure out where in the world the money would come from to buy the prairie. I wrote to Mr. Barnes that summer, very discouraged. He called me and said, "Well, you've talked to all these people, why don't you get them together and I'll come up from Indianapolis, and we'll see what we can do." That was the beginning of the Hoosier Prairie Committee, which first met in my home in September, 1969. I had sent Dr. Lindsey our latest plant list, and two days before our meeting I received a letter from him giving the prairie (at that time he called it the Schererville Prairie) a No. 1 priority rating for preservation. So we met--there were about twenty-five of us, most of whom didn't know each other. Now we're all buddies, but then they were all so impressed by each other. I must say that I think that really did it. You know, "If he's here, it must be important" and vice versa. We decided to try to save the whole thing, not just 40 or 80 acres, but all of the 300 plus acres. I think Dr. Betz named it Hoosier Prairie to impress the people downstate; Lake County is the stepchild of Indiana, and that was our public relations push, which proved to be very fortuitous.

Dr. Herman Feldman of Indiana University Northwest, at that time chairman of the Division of Arts and Sciences, was at our meeting, and suggested that the scientists prepare a report on the prairie to present to the owners so they would know what they had before they sold any more of it. It was all owned by one family in Chicago, and we knew that Highland had tried to buy part of it for a golf course. The pressure was on us to persuade the owners to hold it until we could find a way to save it. Our Scientific Subcommittee, chaired by Dr. Richardson, prepared the report, which included a plant list, letters of support, etc.

Dr. Feldman and others at Indiana University had gotten the support of the administration. The approach to the owners was made by one of the outstanding men in Indiana, Chancellor Herman Wells, who is also president of the Indiana University Foundation. He and Dr. Feldman met with the family in 1970. The next year the Foundation hosted a luncheon for the owners following a tour of the prairie. We were hoping that the owners would donate the prairie, or that foundation funds could be found to purchase it. The owners were impressed but decided they were not in a position to donate it; they would try to hold it until some way could be found to preserve it. And they did hold it, except for 13 acres (5.3 ha) which were destroyed in 1973 for an expansion to the tank farm; they said there had been a prior commitment for that.

I must say that a lot of luck has gone into this project. In 1971, Edward Roush, the Congressman who had introduced the first Dunes bill, was returned to Congress, and he offered to introduce a bill to expand the Indiana Dunes National Lakeshore. The president of the Save the Dunes Council, Sylvia Troy, was on our committee, and she appointed Paul Strand and me to the committee, which was to select the areas that should be included in the expansion bill. We convinced them that the Prairie should be included because it is an integral part of the ecology of the Dunes, as part of the ancient bed of glacial Lake Chicago. The bill was introduced in 1971.

Until then we had had absolutely no publicity. Early in 1972, we held a meeting at the Highland Town Hall for the town boards and park boards of the three towns involved. Town board members had been approached before the meeting by Committee members who lived in their towns, and had been given copies of the report, so they were prepared. Our experts made presentations, and we showed slides of the Prairie. It really paid off. We've had wonderful support from all of the town boards. They all supported the Prairie in testimony to Congress, and two of the towns have included it in their master plans as open space.

Reporters began asking for information about the Hoosier Prairie, and our publicity started. I began talking and showing slides to dozens of groups, ranging from conservation organizations, garden clubs and women's clubs to civic organizations and technical societies. I accepted all invitations to speak, with audiences ranging from six to over a hundred people. We have been on radio and television programs, and have had very good editorial support from all of the newspapers. We also started meeting with our Congressmen and Senators, and obtained their support. But there was no action in that session of Congress and the Dunes bill dies at the end of 1972.

In 1973, a new bill was introduced. The National Park Service study team did not recommend inclusion of the Prairie in the bill; they said it was a detached area and would be too hard to manage. I remember a meeting at the Lakeshore headquarters. Nathaniel Reed, Assistant Secretary of the Interior, was looking at a map of the proposed expansion, pointed to the Hoosier Prairie and said, "What's this? It looks like a natural for The Nature Conservancy." It was ten miles away from the rest of the areas in the bill. He suggested that I call Pat Noonan, president of TNC, so I did. The Conservancy had been interested in the Prairie since 1969 but had not been able to acquire it. We agreed that this was too big a project for TNC unless it was authorized by a government agency. Mr. Noonan offered the Department of the Interior TNC's services in acquiring the Prairie if it was included in the Dunes bill. John Humke and Dennis Wolkoff later testified to that effect before Congressional committees.

Then we had another lucky break. In November, 1973, Indiana University Northwest had a luncheon to announce its expansion plans. Dr. Feldman invited me, just in case there was someone there who could help. State Senator Ralph Potesta of Hammond walked in late. I had gone to elementary and high school with him, but I hadn't seen him for more than 30 years. There was an empty seat next to me, so I waved, he came over and sat down, and we started talking. Of course, if I talk, I talk about the Prairie, and he sounded interested. He said, "Why don't you get some information to me? I may introduce a bill." This was the first time anybody thought there was any chance of getting anything from the State of Indiana! I stopped at his office on my way home and dropped off a copy of the National Natural Landmark study. He introduced a resolution urging the Department of Natural Resources to acquire the Hoosier Prairie as a nature preserve. The resolution was strongly supported by the Izaak Walton League, and I testified at two hearings in Indianapolis. The resolution was amended to call for a study of the feasibility of acquiring the Prairie, and passed. I shouldn't forget to say that you have to try everything to get support. We have a Democratic county in a Republican state. I needed the support of the Governor. I talked to the publisher of the local newspaper; he made a contact for me, and I was able to talk to Governor Otis Bowen when he visited Lake County.

The first hearings on the Dunes expansion bill were held in June, 1974, before the House Interior Subcommittee on National Parks and Recreaction. Many members of our committee went to Washington to testify. Dr. Betz, Dr. Feldman, Dr. Mark Reshkin, George Bunce, and I all testified in support of the inclusion of the Hoosier Prairie in the bill, as did Governor Bowen's representative. The IUN officials also testified that they would be willing to manage the Prairie under contract with the National Park Service. Senate Interior Subcommittee hearings were held in September, 1974, and several of us went back to testify. Committee members in both the House and the Senate kept asking, "Why can't the State buy the Prairie?" The Dunes bill died again at the end of the year.

In 1975, the Indiana Department of Natural Resources study on the feasibility of State acquisition of the Hoosier Prairie was vary favorable. Senator Potesta introduced a bill to appropriate $1,024,000, the appraised value of 331 acres (134 ha), which included an adjacent 31-acre (12.5 ha) farm we wanted as a buffer area. Senator Potesta was a Republican in the Republican controlled Senate, but the chairman of the Finance Committee would not hold a hearing, and the bill died. We had been advised to also try to get a line item in the House budget, and we had another lucky break. State Representative Phillip Bainbridge is a Democrat from Highland, and part of the Prairie is in his district. The Democrats had won control of the House in the fall elections, and Bainbridge was elected Speaker of the House. I sent him a packet of articles and editorials, and asked him if he could get a line item in the budget. We talked and wrote to members of the Lake County delegation, and the Hoosier Prairie was included in their list of priorities. And on the last day, $1,000,000 was put into the budget for the Hoosier Prairie. It was knocked out by the Senate, but restored in conference! Fortunately, Senator Adam Benjamin of Gary was on the Conference Committee, and part of the Prairie was also in his district.

In the meantime, we have a new Dunes bill in Congress. I'm scared to death that the Prairie is going to fall in the cracks. A million dollars might not buy it; we had no reason to think that the owners would sell for that price. We went to Washington again for the House hearings in May, 1975. We had more good luck: our Congressman, Mr. Madden, had become chairman of the House Rules Committee, a very important position. The House Interior Subcommittee marked up the bill on July 29th, and the Prairie was dropped. I went back to Washington and lobbied. You really need good shoes to walk in those marble halls. Mr. Madden used his influence, and on October 30, 1975, the full House Interior Committee put the Prairie back in the Dunes bill, provided the State paid 50 per cent of the purchase price. The Save the Dunes Council has a man in Washington who worked with the committee staff to come up with this compromise, so that both the State and Federal governments would have to pay part of it, rather than each saying to the other, "You do it." They would both have to do it, and something would get done, and it worked out that way.

The Nature Conservancy started negotiations with the owners in the summer of 1975, and my Christmas present was a call from Dennis Wolkoff, Indiana Field Representative of TNC, that he had a verbal agreement with the owners of the 300 acres and they were willing to sell at the appraised valuation of $900,000. The owners signed the option; that was kind of touch and go for a while; they were starting to think that maybe they should have it re-appraised. The State Budget committee authorized spending the $900,000 provided there was a 50 per cent grant from the Federal government. That really took some doing. All but one of the Indiana Congressmen, the Indiana Senators, and the Illinois Senators wrote to Secretary of the Interior Thomas Kleppe. Governor Bowen made a personal call to him, and I understand that Nathaniel Reed really went to bat for us to get the $450,000 grant from the Secretary's Contingency Fund. It was announced the day after the primary election in May. The Conservancy's option was turned over to the State of Indiana, and the State has exercised the option.

In the meantime, back in Washington, the Dunes bill passed the House early in 1976. A Senate bill was finally introduced and hearings were held on May 26th. That was my fifth trip to Washington in two years. The bill was marked up by the Senate Interior Committee in August. We don't know the exact wording, but we understand that the Prairie will remain within the authorized boundaries of the Indiana Dunes National Lakeshore, so I have hopes that sometime the Hoosier Prairie will become a part of a network of prairies within the National Parks system, even if the State retains title to it.

It's been a wonderful experience, in a gruesome sort of a way. I haven't gone into all of the nightmares, such as the time we went there not knowing the thirteen acres had been bulldozed. We do have a happy ending, and now if we can manage it without damaging it, we will have reached our goal.

EPILOGUE

The bill to expand the Indiana Dunes National Lakeshore including Hoosier Prairie was passed by the Senate on September 24, 1976. Because of amendments, the Senate version was sent back to the House and, after some nerve-wracking last minute maneuvers, was approved by unanimous consent on September 29th, in the last day of the session. President Ford signed the bill on the last possible day, October 18th. The State is acquiring the 300 acres. The National Park Service will buy the 31-acre corner farm.

ACKNOWLEDGEMENTS

I cannot give enough credit to all the many individuals and organizations who have helped make an impossible dream come true. I do wish to give special thanks to Dr. Feldman, vice chairman of our committee, whose advice and judgment have been invaluable; to Maxine Krecker, our secretary, for her help and the key role she played in getting Speaker Bainbridge's support; and to my husband, Bob, our treasurer and photographer, for his patience and encouragement when everything looked hopeless. It would take a book to tell the whole story; Dr. Feldman has talked about writing one, and I hope to hold him to it.

WISCONSIN'S WEED LAW
(In the Court - and in the Capitol)

Lorrie Otto

9710 N. Lake Drive
Milwaukee, Wisconsin 53217

ABSTRACT

Environmental educators are asking for better care of the earth and its supporting life. By law a citizen is frequently forbidden to do this. In Wisconsin, a cutting ordinance was taken to court and a natural landscaping bill was introduced into the legislature. On April 21, 1976 in Waukesha County, Circuit Judge William Gramling ruled that the 12-inch weed and grass cutting ordinance, as it applied to the subdivision where defendant Donald Hager lived, was unconstitutional and counter-productive.

INTRODUCTION

Environmental educators in Wisconsin are encouraging the use of native plants in home landscaping, but the enforcement of archaic weed laws prohibits prairie restoration projects. Arguements which surface to oppose non-lawns usually cite one of the following reasons: RATS, FIRE HAZARD, POLLEN, MOSQUITOES, AESTHETICS (PROPERTY VALUES), "WEEDS". During the winter of 1975-76 most of these charges were answered in the City of New Berlin v. Donald C. Hager court action. Concurrent with this procedure a bill to allow natural landscaping was introduced into the legislature which would also update the weed laws so that roadsides and vacant lands could be rejuvenated by plant succession.

On April 21, 1976, Circuit Judge William Gramling ruled that a local ordinance requiring subdivision homeowners to trim grass and weeds to 12 inches was unconstitutional and also observed that it was counter-productive. This decision in the Waukesha County Court reverberated across the country. Examples of newspaper headings were: "Suburban Scientist Marches To Sound of Different Mower" (New York Times), "Court Lets Biologist Skip Mowing His Lawn" (Portland Oregonian), "It's Sow Lawn For Awhile" (Washington Post), "Neighbors Trying To Weed Out Biologist Mowed Down In Court" (Minneapolis Tribune), "Suburbanite Cuts Down Law, Not His Grass" (Kansas City Times), "The Grass Isn't Greener - But It Is More Interesting" (Red Wing, Minnesota), "Compulsory Lawn-mowing Unconstitutional" (Environment June '76). An editorial from Bangor, Maine gleefully declared, "It gives you a good feeling to know that after 200 years, a homeowner, a propertied individual, can push back against the crush of regulations, ordinances and the like, and come out the winner." The defendant, wildlife biologist Donald Hagar was a hero to the news media because he had beaten city hall and also because he did not submit to the insidious peer pressure which forces suburbanites to mimic each other and preen their yards into lifeless, artificial landscapes. He broke the pattern and made the news. No one observed that this was a victory for the flora and fauna, nor was this emphasized at the trial. In his decision, though, the Judge did say that Hagar attempted to cultivate the two and one-half acres surrounding his house in a manner "sensitive to the environment and wildlife".

METHODS, RESULTS, DISCUSSION

The two years of Hagar's legal maneuvering were funded by prominent environmentalists. It was a $4,000.00 adventure which accomplished three things: it exposed and publicized the codes which local government employs to control a citizen's use of his private property; it brought some of the marvelously obnoxious features of the law to the scrutiny of the Court; and it accumulated and organized information which the public and the legislators need to know before attempting to change the law. The courtroom became an environmental classroom.

The weed law in Wisconsin defined Canada thistle, field bindweed and leafy spurge as "noxious" plus any other such weeds as the governing body of any municipality declares to be noxious. Decades ago this may have been a reasonable ordinance. The argument could have been made that local authorities knew best. Today, the local authorities are descendants of people who had no respect, interest or appreciation for the diversity of plant and animal life. They make long lists of plants which they don't like and often add "grass" or "any rank growth". They make the judgment against the plants usually after a neighbor complains, and they also make the aesthetic judgment against the yard of artist, naturalist or scientist. The law does not require a municipality to warn a citizen before his yard is mowed, but most cities do precede the activity with a threatening notice marking the reprieve time in hours. When a citizen attempts to discover the reason for his mowing notice, he is often confronted with myths and misinformation regarding the hazards of his way of life. In addition to weeds, the following are the five most common reasons given, all of which were used prior to or during the Hagar trial:

Rats

One of the early accusations leveled against the Hagar property was that it attracted rats. Forest Stearns, Ph.D., Professor, U.W.-Milwaukee, wrote an open letter to the local newspaper and later submitted an affidavit which stated that "Food is the key to presence of rats - not tall grass". The brown (Norway) rat has adapted to living with man by utilizing concentrated food supplies such as garbage, dog food or grain stored in sacks and bins. In a Baltimore study it was determined that when garbage cans were secured so that dogs could not tip them over, rats disappeared from the area. Rats do not expend their energy in attempting to gather small and dispersed seeds in the tall grass. As expected, when Prof. Stearns examined the 2 1/2 acres there were no trails, burrows, pellets or other indication of rats. When the city officials sent the health inspectors to the property they told Mrs. Hagar that her yard was certainly no health menace, that it was "just a delightful place".

Fire

Yards with uncut grasses are often viewed as fire hazards. No one will deny that dry grass can burn, but people who design a yard of prairie or meadow plants arrange it so that fire is an asset and is also fun when properly used! At the trial, U.S. Forest Service fire expert, David Seaberg, testified that he conducted fuel loading tests in early spring when all grasses and forbs were dry. There was no significant difference between Hagar's unmowed growth and the lot across the street which the weed commissioner mowed once or twice during the growing season. The Court was also reminded that during the growing season, prairie grasses and forbs are green and too succulent to burn. Mowing these and allowing them to dry on the ground actually creates fuel material at a time of year when it wouldn't naturally be there. Mr. Seaberg explained why a grass fire would not be a threat to Hagar's house or any adjoining homes. Because the temperature of fire is reduced by the square of the distance from it and grass fires cannot sustain heat in one spot for more than 15 seconds, Hagar's 20-40 feet of mowed, green lawn barriers were adequate. Philip Whitford, Ph.D., Botanist, U.W.-Milwaukee, who has burned many prairies under prescribed management in Wisconsin, noted that unlike forest or trash fires the tall grass fires do not generate large and persistent embers to be carried in the wind.

Pollen

City officials invariably cite pollen as a health hazard and use this as a justification for mowing private yards. There are 1100 different kinds of grasses growing wild in the U. S. Of these, depending upon the authority quoted, anywhere between 14 and up to 35 would be a generous estimate of those grasses which have anything to do with hayfever. The plants which are noted as important causes of hayfever are divided into three groups: trees, grasses, and weeds. Trees which shed pollen from March through May, include birch, hickory, ash, walnut, oak and elm. Of these oak is regionally important. Grasses which bloom from mid-May to July, include redtop, bermuda, orchard, timothy and Kentucky bluegrass. Kentucky bluegrass is the regionally important grass! Weeds are pigweed, goosefoot and the ragweeds. Ragweeds are the most serious of all the weeds and of all the groups. They cause the most severe and the greatest number of hayfever cases. Ragweed predominates in the pollen count which is published in our newspapers each autumn. We know that pollen can rise 3 miles into the air and float for hundreds of miles, and ragweed is so light and ubiquitous that local control cannot produce measurable results. The Allergy Foundation of America reports that there are a quarter-million tons of ragweed pollen distributed in the central states during one season. Both the giant and the common ragweed begin blooming in August and continue until frost. At the trial, David Kopitzke, Botanist, Milwaukee Public Museum, appeared on the stand with a common ragweed which had 60 blossoms. It had been cut off twice and was less than 12 inches tall - the cutting height of the New Berlin ordinance. Mid-summer mowing which municipalities methodically do, cuts the grasses after they have shed their pollen, postpones but increases production of pollen from hayfever weeds, weakens the perennials and encourages invasion of pollen-producing weeds, while retarding the plant succession which would naturally replace hayfever vegetation. When Philip Whitford appeared before the Judge to explain plant succession to the Court, he carried in his brown paper lunch bag some "New Berlin weeds". He had picked oxeye daisy, sow thistle, wild mustard, bull thistle and ragweeds on the edge of the courthouse lawn. Later, to further emphasize that the law was arbitrarily and capriciously enforced, the Judge was presented with photographs of ragweeds and thistles growing at the mayor's home and other prominent places in the city. If the city were really serious about prosecuting violators it would have been in the unique position of prosecuting itself! If the officials understood the theory of plant succession thay would encourage more landscaping like Mr. Hagar's.

Mosquitoes

Mosquitoes are attracted to dampness. Often lawn watering will bring them in from their breeding areas to roost in foundation plantings, shrubs, etc. All mosquitoes require standing water to complete their life cycles. The minimum time is seven days at optimum temperatures; however, only two of our forty species in Wisconsin can reproduce in such short time. (Kenneth MacArthur, Milwaukee Public Museum). The typical suburban yard converted to native vegetation will absorb and use rain water faster than mowed lawns where most of the water is sheeted off into ditches and culverts. In these metal tunnels out of the wind and the sun suburban mosquitoes blissfully breed! Clogged eave troughs will occasionally contribute to the population. During prolonged rainy seasons all yards will have mosquitoes. A natural yard is again at an advantage because no mowing is necessary. If one wants to roam the paths during mosquito season one should choose the widest ones, but the best place to be is on a screened porch.

Aesthetics

Bobolinks singing in last year's stubble. Meadow larks coasting down to a tent of another season's dried grass. A family of Kestrels romping through old field succession catching grasshoppers and beetles. A field sparrow trying to deflect a mower with her broken wing act. These were happenings at Hagar's! Is this beautiful? The woman who lived next door thought it was not. She and one of her friends and a real estate broker testified that this unkept yard decreased property values by 5 or 10%. Earlier in the trial, Darrel Morrison, Professor, U.W.-Madison, described the aesthetic and environmental reasons for teaching his natural landscaping classes. Perhaps the Judge was thinking of this testimony when he asked the assessor if property values would increase if the idea of natural landscaping "snow balled". The assessor conceded that they would. The final question from Hagar's lawyer, Robert Titley, asked if a person in New Berlin could be different, i.e. Black? The Judge accepted the question as relevant.

CONCLUSIONS

After a delay of three months, the Judge's decision was handed down on April 21, 1976. The Court found nothing in the testimony to justify the fire and pollen hazard and the property depreciation claims by the city (the rat and mosquito accusations were not part of the trial). The Court was of the opinion that the cutting ordinance violates the Equal Protection clause of the Constitution (the ordinance applied to less than one fourth of the city of New Berlin). And the Court observed that the ordinance was counter-productive, noting that Hagar's property, if maintained uncut, would encourage native plants which would crowd out weedy pioneer species. The Court did find that some of the plants from the New Berlin weed list grew on the Hagar property, but in determining the penalty the Court considered the total evidence and Hagar's obvious sincerity and fined him the sum of one ($1.00) dollar and costs. The City had asked that he be fined $10.00 a day commencing two years ago in July 1974!

While the witnesses were preparing for and testifying at the trial, they were also part of a working weed committee. This was composed of representatives from the Agriculture Department, Nature Centers, Parks, the Department of Natural Resources, the Landscape Department and Botany Department of U.W.-Milwaukee, the Milwaukee Public Museum - all experts in land management and plant ecology. They met with Attorney David Kinnamon and advised him as he drafted a Natural Landscaping Bill which would help free citizens from the tyranny of "home rule". People who want to landscape with wild flowers and grasses would be encouraged to do so. The Legislative Purpose reads as follows: "The legislature acknowledges the desirability of permitting and encouraging the preservation and restoration of natural plant communities in urban, suburban and rural areas. It further acknowledges people's need to enjoy and benefit from the variety, beauty and values of natural landscapes and seeks to guarantee the citizens of this state the freedom to employ natural landscaping as a viable and desirable alternative to other conventional modes of landscaping. The legislature recognized that a limited number of plant species may be serious pests, or in some instances may adversely affect human health or safety; in these instances it has provided limited remedies to both local and state governments to deal with specific problems." A natural landscaper would file a management plan with the local officials which would let them know what plant communities were in the yard, what others were expected to come, and also to alert them to the fact that the property is being supervised and cared for. These land owners would be subject to a uniform State weed law which all citizens must obey. The State weed list was reviewed and revised to include only those plants which the experts viewed as hazards (Canada and nodding thistles, leafy spurge and field bindweed. Also, ragweeds would be prohibited within municipalities but not on farm land).

Officials of local governing bodies have not addressed themselves to the possible consequences of caging children in an endless sea of mowed grass. What happens in a society when the young are not stimulated by a diversity of life? Will the dullness of the environment be echoed in the human mind? At the New Berlin trial we've seen how the shaven earth motif allowing no other choices diminished aesthetic appreciation to "you-must-look-like-me". A condition which results in a population with its creative, intellectual and artistic spirit hampered and withering might well be the greatest hazard of all?

To supplement this paper, copies of the affidavits, briefs and the decision are available from Kinnamon - Titley, Quarles and Brady, 780 N. Water St., Milwaukee, Wisconsin 53201; copies of the natural landscaping bill from Lorrie Otto, 9701 N. Lake Dr., Milwaukee, Wisconsin 53217.

THE INADEQUATE POLITICS OF ALDO LEOPOLD

Norris Yates
Department of English
Iowa State University
Ames, Iowa 50011

Since the posthumous publication of his A Sand County Almanac (1949) and Round River (1953), the reputation of Aldo Leopold, both as one of the fathers of ecology in North America and as a humanist, seems not merely secure but still growing. Stewart Udall, then Secretary of the Interior, wrote, "If asked to select a single volume which contains a noble elegy for the American earth and a plea for a new land ethic, most of us at Interior would vote for Aldo Leopold's A Sand County Almanac" (Udall 1963). Roderick Nash judged Leopold's philosophy of wilderness "comparable in acuteness and influence to that of Thoreau himself," and declared Leopold's views to constitute a "synthesis of the logic of the scientist with the ethical and aesthetic sensitivity of a Romantic" (Nash 1973). The most thorough study yet of Leopold's intellectual development and professional career includes the statement, "His enduring achievement was to integrate the two strands--the scientific basis and the conservative imperative--in a compelling ethic for our time" (Flader 1974). A review of this book bears the headline: "Aldo Leopold: Standing Taller With the Years" (Oehser 1975). However, these justly favorable verdicts pale beside an outburst like, "The late Aldo Leopold...was both a better writer and a better naturalist than Thoreau" (quoted on the cover of A Sand County Almanac, 1949). Such undiscriminating praise is regrettable. Leopold should not be turned into a cult-hero.

My purpose, therefore, is to emphasize the limitations of Leopold's attitudes toward people and land; this necessarily involves recognition of the unusual breadth and significance of those attitudes. With rare perceptiveness, Leopold saw that problems of the environment were also problems about people. He concluded "Conservation Esthetic" with "Recreational development is a job not of building roads into lovely country but of building receptivity into the still unlovely human mind." Speaking as a professional wildlife manager to other professionals, he stated, "We find that we cannot produce much to shoot until the landowner changes his ways of using land, and he in turn cannot change his ways until his teachers, bankers, customers, editors, governors, and trespassers change their ideas about what land is for" (Leopold 1940). Part of "Good Oak," one of the most effective pieces in A Sand County Almanac, is a pungent commentary, in reverse chronological order, on the environmental history of Wisconsin and on how mistakes made by farmers, administrators, and policymakers contributed to that history. And in his most significant essay, "The Land Ethic," he challenges people, not burr oaks or priaire dogs, to develop an "ecological conscience."

Further, both his professional and popular writings owe a good deal to his exceptional activity in the political sector--exceptional at least for a full-time forester, professor of wildlife management, and research scientist. As early as 1915, "He became involved, through wide-range personal contacts, in battles for federal legislation dealing with refuges and migratory waterfowl" (Flader 1974), and helped to organize the New Mexico Game Protective Association, one of the first state-wide bodies of its kind. As Secretary of the Association he worked for the formation of a state conservation commission; his role in the so-called "awakening of New Mexico" earned him a personal message from Theodore Roosevelt that "Your association in New Mexico is setting an example for the whole country" (Anon. 1948). He even left the U. S. Forest Service in 1918 for the post of Secretary of the Albuquerque Chamber of Commerce, the more effectively to promote the cause of game conservation, although he rejoined the Service the next year. In Madison, as Associate Director of the federal Forest Products Laboratory, he became "a key figure in the effort that culminated in Wisconsin's Conservation Act of 1927" (Flader 1974), which created a state department of conservation and a Conservation Commission to make policy for the departmental director. In 1943 he was appointed a member of that commission, having spent years politicking with that body, sportsmen's groups, and state legislators for more funding of wildlife research and more extensive application of research data already available, particularly concerning the state's chronically over-abundant deer herd. Meanwhile, in 1934 he was appointed, along with the Des Moines Register and Tribune cartoonist and conservationist, J. N. ("Ding") Darling, to President Roosevelt's Committee on Wildlife Restoration, and in 1935 he was one of the founders of the Wilderness Society, an organization politically as well as educationally active. Small wonder that he once defined the game manager as a "statesman" who must deal with "economic and social forces in a highly technical field" (Leopold 1933b).

To label this particular statesman conservative or liberal would be meaningless. Basic to Leopold's thinking was the belief that the foundations of the conservation movement must be the private landowner and other citizens, rather than public agencies; one motivation for writing the essays in A Sand County Almanac was his desire to reach at least a portion of the general reading public. When the New Deal was making large-scale purchases of land and spending big for conservation in other ways, Leopold termed such measures "palliatives" and proposed that the federal government instead should subsidize "the private landowner who conserves the public interest" (Leopold 1934). On the Committee for Wildlife Restoration he stood alone against Darling and the chairman, Thomas Beck, in favoring more federal encouragement of conservation research and administration by the states and by private landholders--a position traditionally associated with conservatism (Flader 1974). He joined the "game cooperative" movement of the 1930's to the extent of organizing one such cooperative; in 1939 it comprised eleven farmers and five hunters from town, including Leopold himself and Thomas E. Coleman, a Madison industrialist and personal friend who later, as State Chairman of the Republican party, was a major influence in getting Leopold appointed to the State Conservation Commission (Flader 1974) and who, later still, in 1946, led a right-wing faction within the party that supported Joseph R. McCarthy for the Republican Senatorial nomination (Griffith 1970).

Yet, as early as 1922, for fighting soil erosion Leopold advocated "radical action," specifically, "that either the state or national government put all land under inspection as to the adequacy of erosion control and force all owners, whether private or public, to conserve their lands or pass title to some owner that will" (Leopold 1946). What farmers, ranchers, and businessmen during the era of Harding and Coolidge may have thought of this aggressive anticipation of the New Deal we do not know, but in 1946 he in effect repeated the proposal. In "The Land Ethic" he stated further that "there is as yet no social stigma in the possession of a gullied farm, a wrecked forest, or a polluted stream, provided the dividends suffice to send the youngsters to college." However, in that essay he omitted any suggestion that federal or state regulation encourage such stigmata.

Conservative, liberal, both, or neither, Leopold, as I have tried to show, preferred to work through regular channels. In that sense, his politics were wholly conventional, some would say naive. From one point of view, the wonder is not that he accomplished so much as a political operator, but that he accomplished so little. It cannot have escaped his ironic notice that the description of erosion problems and the advocacy of government regulation of landowners--both part of a speech he gave in 1922--seemed as relevant to the editors of the Journal of Forestry in 1946 when it was first published as it presumably had to an audience twenty-four years earlier. In addition, there is ample record of his frustrations and disappointments in the arena. In the mid-1940's he began a paper entitled "Conservation Education--a Revolution in Philosophy" by criticizing himself and all others who really believed that "If the public were told how much harm comes from unwise land use, it would mend its ways" (Flader 1974). He never finished this paper; it ends abruptly on a negative note--one more indication of "the quandary in which he found himself when there was no time to wait for a revolution in philosophy" (Flader 1974). Little more than a year before his death, he said in a talk on "Adventures of a Conservation Commissioner" that "a good commission could prevent a conservation program from 'falling below the general level of popular ethics and intelligence,' but no commission could raise its program much above that level except in matters to which the public was indifferent." Referring to the over-abundance of deer in Wisconsin, he added, "An issue may be so clear in outline, so inevitable in logic, so imperative in need, and so universal in importance as to command immediate support from any reasonable person. Yet that collective person, the public, may take a decade to see the argument, and another to acquiesce in an effective program" (Flader 1974). In "The Land Ethic" he cited the failure of Wisconsin counties to make use of the Soil Conservation Act, and a few pages later, asserted, "When the private landowner is asked to perform some unprofitable act for the good of the community, he today assents only with outstretched palm." Years of trying to cope with this self-seeking convinced Leopold that an ethic beyond economic self-interest, based on a biotic view of land and man as one community, was "an evolutionary possibility and an ecological necessity." Even so, his doubts as to if and when this ethic might prevail lend a vein of elegy and irony to many of his essays, and his political misadventures surely augmented that vein. After highway crews had cut down a stalk of cutleaf Silphium, an original prairie plant, he wrote, "This is one little episode in the funeral of the native flora, which in turn is one episode in the funeral of the floras of the world." In "The Green Lagoons" he stated, "It is the part of wisdom never to revisit a wilderness, for the more golden the lily, the more certain that someone has gilded it." In "Round River," he declared that in many cases the abuse of private land was worse than before the conservation movement began. A friend wrote to Flader about Leopold's "basic optimism," but the limits of that optimism are revealed in the "Foreword" to A Sand County Almanac; here he depicts himself as one member of an embattled, even desperate, minority: "There are some who can live without wild things, and some who cannot. These essays are the delights and dilemmas of one who cannot....For us of the minority, the opportunity to see geese is more important than television, and the chance to find a pasque-flower is a right as inalienable as free speech." Further, "We of the minortiy see a law of diminishing returns in progress; our opponents do not." However, "One must make shift with things as they are. These essays are my shifts." Writing for that minority of the general readership who might care was more than an effort to arouse an ecological conscience; it was also therapy self-administered by a dedicated but often frustrated crusader.

Apart from setbacks at the political and educational level, surely one reason for Leopold's frustration was his own inability to face the likelihood that so fundamental a change in people's attitudes as he advocated would involve concomitant changes in the economic system and probably in the political superstructure. Again and again, in his writing, he seemed on the verge of some sort of ideological breakthrough, but appeared to draw back from the brink of discovery. After making the comment quoted earlier about how landowners cannot change their ways until their teachers, bankers, and so on change their ideas, he added, "To change ideas about what land is for is to change ideas about what anything is for." But this revolutionary train of thought ends, as does the essay, in an ambiguous figure of speech: "Thus we started to move a straw, and end up with the job of moving a mountain" (Leopold 1940). Some time during the mid-1920's he wrote, "This land is too complex for its inhabitants to understand; maybe too complex for any competitive economic system to develop successfully." Yet he added, rather lamely, "Of course we must continue to live with it according to our lights" (Flader 1974). Two of those lights were science and a respect for the living earth; how they were to function noncompetitively in a competitive society he did not say. In 1933 he wrote that "the idea of controlled environment contains colors and brushes wherewith society may some day paint a new and possibly a better picture of itself. Granted a community in which the combined beauty and utility of land determines the social status of its owner, and we will see a speedy dissolution of the economic obstacles which now beset conservation" (Leopold 1933a). What would be the attributes of such a community, and how could it be brought about? Earlier in that essay, he had said that in their materialistic stress on commodity consumption, socialism, communism, fascism, technocracy, and capitalism were "as identically alike as peas in a pod." As to the "social pressures" needed to maintain this ideal community, Leopold reviewed one specific and limited possibility--the labeling of manufactured products in such a way as to distinguish "conservation products" from those goods produced by ravaging the land--but he insisted that "I neither predict nor advocate these particular pressures--their wisdom or unwisdom is beyond my knowledge." Many years later, in "Round River," he admitted that "My own gropings come to a dead end when I try to appraise the profit motive." Recognizing that it has failed to motivate the conservation movement because in conservation "the profit accrues to society rather than to the individual," Leopold here chose not to criticize the individualized profit system but simply to insist that "ethical and aesthetic premises" underlay any economic system.

In the political and administrative sector, then, this experienced administrator had little to offer for implementation of his land ethic beyond a very traditional reliance on highminded moral persuasion, and it has remained for others--too few others--to see the sweeping radicalism implicit in Leopold's ethic. Raymond F. Dasmann, who dedicated his first book to "the memory of Aldo Leopold," has shown how the "conservation alternative," as he calls it, will necessitate far-reaching changes in the life-style of the populace, including decentralization of cities, an end to sexual discrimination, and reconciliation in the struggle between "mind and body, man and nature, matter and spirit" in favor of a new "self-identity and awareness" (Dasmann 1959, 1975). Murray Bookchin, an anarchist with ecological awareness, warns that "Either ecological action is revolutionary action or it is nothing at all. Any attempt to reform a social order that by its very nature pits humanity against all the forces of life is a gross deception and serves merely as a safety valve for established insitutions" (Bookchin 1970).

Unfortunately, like Leopold, both critics say too little that is relevant to how these far-reaching changes may be effected. The inadequate politics of Aldo Leopold is still the politics of most environmentalists and their nonscientific supporters.

LITERATURE CITED

Anon. 1948. Aldo Leopold 1886-1948. J. For. 46:605-606.

Bookchin, Murray. 1970. Toward an ecological solution. In Eco-catastrophe. Editors of Ramparts. Canfield Press, San Francisco. pp. 57-82.

Dasmann, Raymond. 1959. Environmental conservation. John Wiley & Sons, New York. 307 p.

Dasmann, Raymond F. 1975. The conservation alternative. John Wiley & Sons, New York. 164 p.

Flader, Susan L. 1974. Thinking like a mountain: Aldo Leopold and the evolution of an ecological attitude toward deer, wolves, and forests. Univ. Missouri Press, Columbia. 284 p.

Griffith, Robert. 1970. The politics of fear: Joseph R. McCarthy and the Senate. Univ. Press Kentucky, Lexington. 362 p.

Leopold, Aldo. 1933a. The conservation ethic. J. For. 31:634-643.

Leopold, Aldo. 1933b. Game management. Charles Scribner's Sons, New York. 481 p.

Leopold, Aldo. 1934. Conservation economics. J. For. 32:537-544.

Leopold, Aldo. 1940. The state of the profession. J. Wildl. Mgmt. 4:343-346.

Leopold, Aldo. 1946. Erosion as a menace to the social and economic features of the Southwest. J. For. 44:627-633.

Leopold, Aldo. 1949. A sand county almanac, and sketches here and there. Oxford Univ. Press, N.Y. 226 p.

Leopold, Aldo. 1953. Round river: From the journals of Aldo Leopold. ed. Luna B. Leopold. Oxford Univ. Press, New York. 173 p.

Nash, R. 1973. Wilderness and the American mind. Rev. ed. Yale Univ. Press, New Haven. 300 p.

Oehser, Paul H. 1975. Aldo Leopold: Standing taller with the years. The Living Wilderness 39:43-44.

Udall, S. 1963. The quiet crisis. Avon Books, N.Y. 224 pp.

INTERPRETATION OF THE CANADIAN PRAIRIE, A CANADIAN WILDLIFE SERVICE PROGRAM

Bob Peart, Head
Prairie Wildlife Centre
P.O. Box 1528
Swift Current, Saskatchewan
S9H 0J5

ABSTRACT

The Prairie Wildlife Centre is responsible for the prairie interpretation program of the Canadian Wildlife Service. The program is a major undertaking which involves a large capital investment including the purchase of approximately 405 ha (1000 acres).

INTRODUCTION

Canada is rocky seas of mountains and magnificent tables of plain, thousands of leagues of spruce woods and fertile miles of farm, frozen white oceans and cities dominating the earth as far as eyes can see. Canada is foggy wet coasts and dry cold deserts, rolling golden grasslands and valleys ablaze with autumn leaves, lonely surf-girt islands and towns teeming with people. This land is many lands, each worth knowing. To glimpse this diversity is to feel some of the meaning of being Canadian.

All Canadians cannot know all of Canada. But most Canadians can know some of the lands that make the whole. To know any land is to acquire understanding, and values and the feelings of belonging that are the key to man's happy and successful living with the surface of Earth (Edwards 1974).

The purpose of the Canadian Wildlife Service Interpretation Program is to provide the opportunity for the public to experience this diversity, this change in the face of Canada and to hopefully assist in the development of positive attitudes toward the environment and natural landscape. The CWS is a branch of Canada's federal government and is administratively located within the Department of Environment. The United States counterpart is the U.S. Fish and Wildlife Service in the Department of Interior.

The CWS began its wildlife interpretation program in 1967. The basic reason the program began was that field biologists working on various projects--whether determining caribou migration routes, conducting breeding surveys for waterfowl, or acquiring and managing habitat for rare and endangered species--felt that, in a time of severe shortage of funds, their projects were dispensible because of man's interference with and lack of concern for the natural principles of the basic web of life. It was felt that our service must also get involved with attempting to make the public more aware of Canada's landscapes and man's effect on this land.

PRINCIPLES AND OBJECTIVES OF THE CWS INTERPRETATION PROGRAM

Canada's diversity and natural landscapes should be used as a framework for the program; therefore, we adopted Rowe's (1972) breakdown of the forest regions of Canada in which he identified 10 separate landscapes or forest units.

The major target groups of the program would be the traveling public and the residents of each of these landscapes. We adopted two selection criteria for the location of the program. (1) All programs must be located on the Trans-Canada Highway or major tributary to reach the travelers and also traverse all the landscapes. (2) Programs must be located within 25 miles of a major town or urban centre.

The piece of land chosen for the program must be representative of the way the land is now being used, not a piece of virgin wilderness. In this manner man's present use of the land can be better illustrated.

Since 1967 three programs have commenced operation and are open to the public. Creston Valley Wildlife Centre in British Columbia tells the story of Mountain Valleys and the Wet Interior or Columbia Forest, Wye Marsh Wildlife Centre interprets the wildlife of the Northern Hardwoods, and Percé Wildlife Centre illustrates the story of the Atlantic Coast and man's interaction with the ocean. The fourth in our series of these Trans-Canada houses will be on the prairies.

<u>Planning the Prairie Wildlife Centre</u>

The Prairie Wildlife Centre is to be located on 316 ha (780 acres) of land near Swift Current, Saskatchewan. The piece of land is quite diverse, with a variety of habitats, including some native unbroken mixed-grass prairie. The purpose of the Prairie Wildlife Centre is to interpret the characteristics of the Grassland Natural Region by emphasizing the familiar characteristics rather than the unique, and by comparing and contrasting these characteristics with the other natural regions of Canada (Peart 1976). The major goal is getting the traveling public out of the car, walking the prairie, feeling the wind, touching cactus, hearing the whistling retreat of gophers, and perhaps, if they are lucky, flushing up a sharptail or an antelope. In Canada, you are traditionally taught in school about "the boring, lifeless, hot, desolate prairie", and the only thing it's good for is growing cereal crops such as wheat. In actuality, as you are aware, to get out of your car, stretch your legs and experience the prairie first hand can be very exciting. We don't expect the traveling public to stop for more than an hour or so, but in that brief time they will have had a firsthand outdoor experience, hopefully to leave with a better understanding and appreciation of the grasslands.

The specific program at the Prairie Wildlife Centre was designed for five basic interpretive principles. (1) Attitude change or knowledge gain is best accomplished when an individual is face to face with the real thing, in this case the prairie landscape. Therefore, everything designed and offered to the public is an attempt to get people out of the car, to walk the prairie, face to face with the real thing. We try to get them personally involved or interested in the various elements rather than have them observe everything as "onlookers" and have everything pointed out to them.

(2) Attitude change or knowledge gain is directly proportional to the number of senses involved by an individual both simultaneously and separately. People will be smelling sage, feeling the pin point of cactus or needle grass, watching waterfowl alight onto the nearby lake or marsh, perhaps tasting cattail root or drinking mint tea, and maybe even listening to coyotes howl at night. A wide variety increases attention span, increases knowledge gain and develops personal interest in the program.

(3) Any building facilities or construction must fit into the landscape both aesthetically and functionally. No construction or alteration of the site would occur until the question "why" was asked and the resulting answer logically flowed from the plan of approaches. In this manner we hoped that an unnecessary or poorly located "white elephant" of a major capital development would not occur as they have all too frequently in other U.S. and Canadian interpretation programs.

(4) Absolutely no program development or any decisions would be made until a plan for interpretation is written. This plan would specify objectives and goals for the program, outline the message we wished to emphasize to program visitors and describe in detail all the major visitor groups who would visit the program. These three criteria, involving objectives, message analysis and receiver study, would then be used to develop the media or approaches to obtain logical results instead of pie-in-the-sky ideas that sounded "neat" at the time.

(5) Feedback or evaluation would be built into everything that was offered to the visitor so that we can constantly check and reevaluate our objectives.

Of the 316 ha (780 acres) of the land that was selected for the centre, about 202 ha (500 acres) are cultivated and used as a 50/50 crop-fallow for growing grain, usually wheat. Some areas have never been broken and are remnants of the prairie and vegetation that were in evidence prior to about 1890-1910 when the settlers moved in. _Stipa_, _Agropyron_ and _Bouteloua_ are the major genera of grass. About 61 ha (150 acres) are seeded to crested wheatgrass (_Agropyron cristatum_) and alfalfa (_Medicago sativa_) and are hayed regularly once every summer. These land use practices and conditions will basically remain the same except for a bit of reseeding to provide more edge for nesting birds.

The Program

Now let us take an imaginary walk through the Prairie Wildlife Centre as the approach and media are presently conceived. The ORIENTATION section slows visitors down and gets them thinking and asking questions about the program. Because of our philosophy and belief that the "real thing" is the best tool for achieving our purposes, the OUTDOOR EXPERIENCE is crucial. Its purpose is to provide the visitor with a prairie experience. The combination and interaction of the land, climate and wildlife are what makes the prairies unique, and it is this interaction and the necessary adaptations for survival that we want to expose to the public.

Once visitors have walked the prairie trail or one of the other trail options, they must pass through the building to return back to the parking lot. At this stage REINFORCEMENT begins. The purpose of reinforcement is to put the grasslands into perspective and the program all together. It will involve people in various activities they can choose depending on their interest, and it will provide an opportunity for us to obtain feedback, evaluate our approaches and test whether our objectives are being met. Carry-away material will be available for the public to use while they continue their drive across the grasslands (e.g., pamphlets on vegetation or maps outlining interesting places).

LITERATURE CITED

Edwards, R. Y. 1974. Know Canada - Understanding through interpretation. Unpublished.

Rowe, J. S. 1972. Forest regions of Canada. Dept. Environment, Canadian Forestry Ser., Publ. No. 1300, Ottawa, Ontario.

Peart, B. 1976. Grassland natural region plan for interpretation, CWS Prairie Wildlife Centre, Swift Current, Saskatchewan.

THE PRAIRIE: A RESOURCE FOR ENVIRONMENTAL STUDY

Dwight R. Platt
Department of Biology
Bethel College
North Newton, Kansas 67117

For those of us from the central United States, the prairie is our natural heritage. There are a few of us, who, like Walt Whitman or Aldo Leopold, can appreciate the intricacy and beauty of the prairie ecosystem. There are a few of us who attend prairie conferences or who earn our livings in the prairie. But for the majority, this prairie heritage has little meaning. To enjoy nature is to go to the woods, to the seashore or to the mountains; few go to the prairie for relaxation and enjoyment of nature. The prairie is a misunderstood and unappreciated natural community. There is need for education about the prairie.

Prairie education is also needed for the broader purpose of environmental education. Environmental education usually focuses on problems, their causes and their solutions -- problems of water pollution, of air pollution, of land use. This problem-solving approach is good, but environmental education also needs to focus on the broader themes of the nature of the world and of the interactions of human and natural systems. For this, we have a great resource in the prairie. For this, we can use prairie education. The need for education about the prairie is both to further an understanding and appreciation of the prairie, and to further an understanding of the nature and dynamics of natural ecosystems with which our human systems must coexist.

At Bethel College in Newton, Kansas, we have been involved in environmental education and in prairie education in a small way. In 1965, Bethel College, with the help of The Nature Conservancy, acquired a 32 ha (80 acres) tract of sand prairie for use by the Biology Department. In 1970, the South-central Kansas Environmental Education Center (SKEEC) was organized at Bethel College to promote environmental education in area schools and communities. From its inception, one of the most popular programs at the Center has been a program of field trips to the sand prairie, the Sand Prairie Natural History Reservation. However, the program was limited because it was dependent upon the voluntary efforts of a few persons at the college. Too often the field trips were isolated experiences with little preparation or follow up.

The people leading field trips became aware of some popular attitudes about the prairie to which a planned program of prairie education should speak. For instance, what answer can be given to a person who looks at dunes covered with rhombic evening primrose and asks, "what good are these weeds you study?" Or, when shown a prairie vole that has been caught in a live trap, the person responds, "what good it it?" One can suggest ways in which the animal or plant might be valuable economically or aesthetically to people, but that reinforces the anthropocentric view of the prairie. One can talk about the role that each animal or plant plays in the prairie ecosystem, but this may not be understood without more intimate experience of the prairie as an ecosystem. The agricultural view of the prairie as a grassland to feed large grazers, needs to be balanced by the ecosystem view, which looks at the role of all native prairie plants and animals in contributing to the survival of the prairie.

Some organized curriculum materials were needed for use on Sand Prairie Reservation, materials that could be used by teachers in planning and leading their own field trips. In 1974, with support from the U.S. Office of Environmental Education, we at SKEEC began to write curriculum materials about the prairie, especially for use on Sand Prairie Reservation. It was decided not to write a complete curriculum about the prairie, but rather to write enrichment materials that could be used with school curricula already being taught, or which could be used by community organizations. The modular format was adopted as the most flexible and useful form for these materials. Each module was to be a self-contained unit, it could be fitted together with other modules for further development of a topic. The 53 modules that have been written include modules that are to be used before a field trip, modules with activities or studies to be used on a field trip to a prairie, and modules to follow up topics studied on the field trip. Modules have been written for various age levels from elementary school to adult. Some of the modules are subjective activities to increase sensory awareness, and to explore feelings evoked by the prairie. Other modules include objective analysis of biological components of the prairie.

The curriculum materials are multidisciplinary. The writers included not only biologists, but also an artist and a sociologist. To serve as a focus of activities in the three disciplines -- biology, art and social studies -- we chose three themes: diversity, interdependence and rhythms. These themes allowed a probing of the ecosystem concept in biology and at the same time were relevant to the other two disciplines.

Insects and other arthropods were included for study in many modules, because they are important animals in the prairie and are easy to observe or collect. To assist identification in studies where it was important to know the animal and its ecological role, taxonomic keys were written to the families of insects and spiders. By restriciting them to arthropods found in terrestrial habitats on Sand Prairie Reservation, the keys could be made simpler. Technical terminology was kept to a minimum and terms were defined at the beginning of each key. At the end of the key, ecological characteristics of the families were listed. Therefore, students can get more than just a name in the process of identification. These keys, with photographic illustrations, can be borrowed from SKEEC by teachers.

One of the studies that can be adapted for a number of age levels involves the observation of animals that are visiting a plant in bloom. A simple flow-chart key that can be used by elementary school students was written to identify the insects that commonly visit butterfly milkweed. A slide set was produced that can be used before the study to acquaint students with some of the animals that visit flowers on Sand Prairie Reservation. After listing the animals, students can explore relations of the animals to the plant, and their ecological role in the prairie. A fairly complex web of ecological relationships can be drawn from just fifteen or twenty minutes of observing one kind of flowering plant.

However, identification of the prairie species is often not necessary. Teachers hesitate to take their classes to study in the prairie because they are unable to identify most of the prairie plants and animals. In many studies, differences can be observed or patterns explored without identifying or giving names. A number of such studies were included in the SKEEC curriculum materials.

Grasshoppers are important animals in the prairie, but few people realize the variety of grasshoppers to be found there, and the different niches they occupy. Many different kinds can be sorted in a small collection by looking for similarities and differences, without attempting to identify or give them names. The mandibles of grasshoppers are differently adapted for different food habits. They can easily be removed, mounted in clay, and observed with magnification. An observational study can be followed by experiments to see what food the grasshoppers actually eat.

Another study explores the meaning of color and color signals in the prairie. An observational study can be followed by experiments to test hypotheses.

Other studies explore and quantify plant distribution patterns. The students then think about hypotheses to explain these patterns and the design of experiments to test these hypotheses. Stratification and zonation of animals on the prairie can be studied as a way to appreciate the diversity of species. Daily and seasonal rhythms can be studied. Experiments may be used to determine some of the mechanisms for timing these rhythms. Why do seeds of prairie plants that matured in the summer not germinate as soon as they are scattered, as most garden seeds do? Experiments with seed stratification can be used to demonstrate one mechanism for timing the germination of seeds.

One of the art modules explores structural diversity. Structures can be classified into types of structural patterns. These patterns can be explored, both in nature and in human artifacts. Students can then visit the prairie with sharpened observations looking for structural patterns, and one of these patterns can be selected back in the classroom to serve as the basis for creative expression in various media.

Some of the social studies modules explore the analogs in human systems, of some of the concepts studied in a biological system. Others explore the relation of man and human systems to the prairie.

Once students are sensitized to some aspects of the prairie ecosystem, follow-up modules can be used to explore conservation issues related to the prairie. These include the disappearance of natural prairie, the delcine and/or extinction of some species, management of habitat for wildlife, and the good management of rangeland.

Curriculum materials such as these can be continually expanded. The 53 modules that have been written were planned for use on Sand Prairie Reservation, but they can be adapted for use on other prairie sites. Each prairie natural area can be used as a biological and aesthetic resource for education of the public, to raise consciousness about their natural environment. Only as more people learn to appreciate the prairie as an ecosystem, will we be able to preserve adequate samples of this natural heritage successfully. Only with an appreciation of the interdependency of human systems and ecosystems, will we be able to solve our environmental problems effectively.

PRAIRIE MODELS FOR AGRICULTURAL SYSTEMS

Lon Drake

Department of Geology
University of Iowa
Iowa City, Iowa 52242

ABSTRACT

Although highly successful, modern U.S. corn belt agriculture includes: high energy and fertilizer consumption; excessive erosion, soil depletion and compaction; monocultures resulting in extermination of most other species; and inefficient utilization of available solar energy, precipitation and nutrients. By contrast, the tallgrass prairies had a smaller net budget for energy and nutrients but utilized them more efficiently, while conserving water and enhancing soil productivity. It may be feasible to model a profitable mechanized agriculture after the prairie systems to achieve greater efficiency and reduce some of the current problems. A first approximation of a prairie model could be the attempt to grow wide-spaced corn in permanent alfalfa, harvesting both. Options for refinement toward a second approximation are discussed.

INTRODUCTION

U.S. corn belt agriculture is a success story that is the envy of the nations of the world. Yet in this decade it has been subject to increasing criticism from many sectors. Pimental et al (1973) demonstrated that energy efficiency has decreased over past decades and that the single largest energy expenditure is for production of fertilizer. The instability of monocultures has become more widely appreciated since the southern corn leaf blight damaged crops in 1970, and the narrowing of crop gene pools has been widely deplored (Miller 1973). According to Wade (1972) the National Research Council warns that we "are increasing the probability of major crop epidemics." Fence-to-fence planting has decreased wildlife habitat to the point that Paul Christenson (pers. comm.) estimates that one-half of Iowa's pheasants are produced from nests in roadside ditches, whereas the Iowa Conservation Commission notes that roadsides "...provide most of the suitable nesting cover..." (Dale 1976). The increased erosion which accompanies fall plowing and expanding acreages of row crops has been long recognized but largely ignored. Today the accelerating rate of soil loss has become sufficiently obvious that the chairman of the National Corn Growers Association has recommended a shift away from corn and soybeans, turning instead toward oats (Sandler 1976). The presence of vast monocultures invites expansion of pest populations, with additional energy needed for control which results in undesirable environmental side effects (vandenBosch 1972).

Nearly seven billion dollars worth of fertilizer nutrients are lost to erosion each year (Beasley 1972). The social and ecological significance remains more poorly defined. On one hand we find environmentalists estimating that"...a minimum of 55 to 60 percent of the nitrogen load as nitrate in the surface waters of this watershed originated from fertilizer nitrogen" (Kohl et al 1971). Nitrate contamination of groundwater has been widely documented (Lee 1970). Concern has been expressed that heavy applications of fertilizer may have a causal relationship to the general increase in human cancer (Sanders 1971), and subsequent research has indicated that over one hundred nitrosamines are carcinogenic in laboratory animals (Magee 1973). On the other hand, representatives of farm groups and fertilizer manufacturers claim that "fertilizers did not add significant amounts of nitrogen and phosphorus to stream flows" (Coffman 1971). Given the complexity of the nitrogen cycle, diversity of soils and the limitations of sampling schemes, the end members of the evaluation spectrum can both readily find support for their respective biases.

Less widely recognized is the loss of water itself. Accelerated runoff removes water which could have been used to increase subsoil reserves rather than aggrevating a flood problem downstream. Dredging 450 million cubic yards of sediment from U.S. waterways to maintain navigation now costs over $250 million annually (USDA 1968) and over $100 million of reservoir capacity is lost each year through siltation (U.S. Geol. Sur. 1972). The inefficient use of available solar energy goes virtually unrecognized. For example, during 1976 in eastern Iowa, the first cutting of hay was taken in the first week of June. Corn was then about six inches and soybeans two inches high. During April, May and early June, available solar energy was expended mainly on plowed soils: evaporating soil moisture, oxidizing organic matter, increasing surface sealing and abetting compaction.

Overall, some people doubt that such practices constitute a stable system (Rappaport 1971) especially in the face of shifts in energy pricing and uncertainty of supply. The agricultural establishment has been charged with "inept management, poor research" (Wade 1973) and a lack of leadership (Hadwiger 1975), partially because of its lack of interest in these problem areas. The report of the Comptroller General to Congress (1977) was quite critical of the conservation effort obtained from federally funded programs (although I consider some of their criticism to be in error).

PRAIRIE EFFICIENCY

By contrast, the tall grass prairie, which formerly occupied much of the present corn belt, had a smaller net budget for energy and nutrients but utilized them more efficiently. Cody (1974) claimed that "natural selection produces optimal results unless constrained by history or by competing goals" and the prairie appears to conform to this dogma. Review of the literature on erosion shows that when prairie is converted to pasture, erosion rates increase by nearly an order of magnitude and when converted to row crops erosion rates increase by another order of magnitude. The prairie-cropland contrast is succinctly illustrated by Weaver and Harmon (1935) from observations near Lincoln, Nebraska: "During a rainfall of 5 inches (12.7 cm) over a period of two days, the runoff from a native prairie on a 5° slope was only 3 percent, all clear water. On a similar slope only 35 feet (10.7 m) distant in wheat stubble, the runoff was 28 percent and more than 1/100 inch (0.03 cm) of surface soil was washed away..."

The importance of aged organic matter in maintaining soil quality has probably been underestimated. Alexander et al (1968) note that in native prairie of Illinois, the Muscatine soil types "...not only have the highest total organic matter content, the highest root weight of Andropogon gerardii... but also the highest yields of grain crops under modern agricultural practices." In virgin prairie soils, much of the organic matter is in the form of colloidal humates, gums and resins along with fine fibers which coat and separate soil particles, have large surface area and efficiently soak up nutrients and water. When dated by C^{14} the humate fraction often averages hundreds to thousands of years old (Paul 1969), which is a minimum age for establishment of its dynamic equilibrium (Neumann 1974). Plowing, which exposes the humates and fiber to light and oxygen, is probably the single greatest factor in the breakdown of useful organic matter. Also, on bare ground "the raindrop impacts break down many aggregates...permitting the organic material to be floated from the field" (Ellison 1948). Repeatedly row-cropped soils may still register a moderately high organic content when measured by standard combustion analysis, but much of this consists of large fragments of young cellulose which contributes little to soil quality.

Deep rooted perennials probably act as pumps, bringing up nutrients which later become available to the rest of the biota through decay or burning. The deep loess deposits that blanket much of the corn belt are especially suitable for deep root penetration and nutrient pumping. It is often supposed that plants are important agents for chemical weathering. Cleaves et al (1970) demonstrated that the rates of chemical weathering in humid areas have been grossly underestimated by earlier research. Cawley et al (1971) found that "the rate of chemical weathering in central Iceland is two to three times more rapid in areas with plant cover than in barren areas." Similar research is lacking in temperate regions. However, with the current tendency to view soil as a nearly passive growing medium, we may be underestimating the ability of perennial polycultures to supply their own nutrients by accelerating the weathering of soil minerals.

TOWARDS A FIRST APPROXIMATION

The comparison between the functioning of row crops and prairie suggests an agricultural compromise that might reduce erosion and energy losses while allowing the modern form of mechanized agriculture to continue to be profitable. When viewed broadly, I see the single largest advantage of the prairie, as an efficient soil and food producing unit, characterized by a perennial ground cover that is supplemented by ecologic diversity and other assets such as nitrogen fixing legumes. A field of alfalfa meets some of these conditions and has the ability to consistently produce more plant protein per acre than any other common monoculture.

The disadvantage of pure alfalfa of course, is that the food energy is in a rather dilute form and the midwestern farmer has economic incentive to produce grain as a high energy feed to make his livestock gain weight rapidly. It should be noted however that some farmers still show a profit on stock cattle that gain weight more slowly but less expensively on pasture and hay or silage - and others are finding "organic" farming to be profitable (Lockeretz et al 1975). With proper management on good soils, alfalfa yields about the same profit per acre as corn, although in practice this potential is often unrealized because farmers tend to devote their best land and management to the corn acres and the alfalfa fends for itself on slopes too steep or rocky to put into corn (Frank Schaller, pers. comm.).

Corn and alfalfa are favored by midwestern agriculture because they yield the greatest quantities of nutrients usable by livestock (usually expressed as total digestable nutrients - TDN). At 87.08 hectoliters per hectare (hl/ha; equivalent to 100 bushels/acre), corn produces over 2,268 kg (5,000 lbs) of TDN. Alfalfa yeilding 8,967 kg/ha (4t/acre) produces over 1,814 ks (4,000 lbs) of TDN. The TDN yield from small grains is considerably less. For example, oats at 65.3 hl/ha (75 bu/acre) yields about 771 kg (1,700 lbs) of TDN if used as grain, or 1,134 kg (2,500 lbs) as silage or hay (Van Doren and Hays 1958). However, since the costs, risk, timing and equipment required for oats are also less exacting it can still be a profitable crop.

Wide-spaced corn grown in permanent alfalfa would constitute a first crude approximation of a prairie model. This combination crop would provide a permanent ground cover, a grass-legume mixture, deep rooted perennials and at least somewhat greater diversity. A very early cutting of hay (third week of May) could be followed immediately by a late planting of corn (chisel planting or narrow disced zone). If the corn rows were spaced widely (1.83-2.74 m; 6-9 ft), cultivation might be replaced by a second cutting of the alfalfa to reduce competition to the corn. Narrow gauge equipment would, of course, be needed. Per hectare yields of only half that of conventional farming may be quite acceptable because both hay and grain would be coming from the same area. For example, a farm currently producing 121.4 ha (300 acres) of corn and 121.4 ha (300 acres) of alfalfa separately would have the same net yield if all 242.8 ha (600 acres) were in a corn-alfalfa combination producing only one half the conventional yield per area of hay and grain. Improved retention of water and nutrients may aid net productivity and differences in rooting depths may reduce competition. If conservation of nutrients, energy and soil were sufficient, then even lower yields might be economically acceptable.

Alfalfa is a deep-rooted phreatophyte whose roots have been traced to a depth of 20.1 m (66 ft) beneath the surface (Meinzer 1927). Research in Utah (White 1932) indicated that when soil moisture was abundant at shallow depths, the plant obtained much of its water from shallow side roots. When shallow moisture became scarce, alfalfa shifted its dependence to the tap root in the deeper supply. This may represent conservation of extra energy required to pump from greater depths. Corn is shallow rooted (about 1.22-1.52 m; 4-5 ft), and if interplanted with alfalfa, both may be able to utilize soil moisture at different depths without excessive competition.

Thick loess (moderately permeable) over glacial till and Sangamon paleosol (nearly impermeable) is a common geologic succession throughout the corn belt. This stratigraphy results in a perched water table within the lower loess and makes an ideal situation for phreatophytes like alfalfa, which favor well-drained sites. A number of arid-region phreatophytes like saltgrass, willow, greasewood and rabbitbrush apparently exercise the water-depth option (Robinson 1958) and suggest the possibility that some of the deep rooted species of the tallgrass prairie may also be phreatophytes using the same strategy.

Most hay and pasture legumes in the midwest produce more than 112 kg of nitrogen within the soil per hectare (100 lbs/acre) per year. The notion of inducing nitrifying bacteria to live on the roots of grain grasses is now receiving serious consideration (Smith et al 1976, Phillips et al 1971). However, it may be more realistic to develop a technology for intercropping the already successful legumes with compatible grains. The runoff conserved by the year-round ground cover will be partially consumed by the ground cover during the growing season. The net balance will vary widely with slope and rainfall intensity, but most of the water will be used rather than lost.

Pollination of corn in 1.83-2.74 m (6-9 ft) rows is not likely to be a problem. Corn was developed by ancient agriculturists who probably used widely spaced rows or scattered hill plantings intercropped with beans, squash, cotton and weeds. Hybrid seed corn is commonly produced today by alternating six rows of detasseled plants with two rows of pollinators and pollination is adequate.

TOWARDS A SECOND APPROXIMATION

The first approximation can only be expected to be useful at the research level to help set the stage for refinements. Modern hybrid corn is bred to flourish in thoroughly cultivated and heavily fertilized fields which warm up early and are free of other plants that would compete with the corn. Older open-pollinated and "Indian" corn races are considerably less demanding and produce smaller yields although they may have a higher protein content (Perelman 1972). The stalks of some varieties of Indian corn have high sugar content and are relished by cattle even in early winter (personal experience). Breeding might lead to varieties whose stalks could serve as an energy supplement. The resulting corn stubble and standing hay would then help support stock cattle at low cost in late fall and early winter.

Grain spills along country roads and railroad tracks often produce a few corn plants which successfully compete with the weeds. This suggests that greater competitive ability might even be bred into modern types of corn. Because the ground cover will compete with the grain mainly for moisture (personal experience), an alterantive to corn may be an energy grain already adapted to less rainfall, such as grain sorghum. Grain sorghum has approximately the same livestock feeding efficiency as corn (U.S.D.A. 1960) and can be substituted for corn in most feeding programs. The green stalks of some varieties contain prussic acid in quantities which would be detrimental to pre-frost grazing (Quinby and Marion 1962). However, other varieties have stalks with a high sugar content (like those used for sorghum syrup) and it should not be difficult to breed a suitable sorghum compromise for an inter-cropped hay-grain economy.

The only legumes which seem capable of producing a truly permanent stand in the midwest are bird's-foot trefoil and crown vetch. All others, like alfalfa and the various clovers, gradually decline in numbers and are commonly replaced by bluegrass. The alfalfa suggested for the first approximation would be adversely affected by the competition from the corn and after three to ten years could be expected to become a minor component in the permanent ground cover, being replaced by grasses. Use of a creeping variety (such as "Rambler") might prolong its dominance through self-seeding but would reduce the volume of cut hay. Both bird's-foot trefoil and crown vetch are notably unaggressive in the seedling stage and usually must be sown alone the first year to achieve a full stand. Therefore, for well-drained and moderately-drained soils, a second approximation might be to establish a ground cover of crown vetch the first year, overseed with alfalfa the second spring and after the first early hay cutting, interplant rows of grain sorghum. This technique may provide for a longer dominance of legume in the ground cover (and hay) as the alfalfa fades. On more poorly-drained soils, bird's-foot trefoil and an "improved" corn may be a better combination. A few low-growing, shallow-rooted, shade-tolerant species might also be included to increase the density of the ground cover and provide additional diversity. Dutch white clover offers little additional competition to the major grain or hay crops and provides good forage for bees which in turn would help the major legumes perpetrate themselves through self-seeding.

Alleleopathic competition may aid or negate some potential combinations. I have experimented with intercropping oats (plant early) and soybeans (plant late) for erosion control. Mature oats appear to have a more adverse effect on young soybeans than can be attributed to simple mechanical competition. Mature wheat, on the other hand, seems quite compatible with young soybeans and my limited experiments suggest that this grass-legume combination can be successfully intercropped where summer rainfall is adequate (east of the Mississippi River). However, oats do make a fine nurse crop for legumes like alfalfa and sweet clover and perhaps do so because of allelopathy towards the weeds. Much of what we blithely refer to as "competition" between weeds and crops may turn out to be an aggressive chemical antipathy rather than passive mechanical competition for light and water. In those cases where nurse crops are especially successful, there is even the possibility of synergistic allelopathy where two species coordinate chemically to exclude other species. This would form a "defense guild" different in design from those described by Atsatt and O'Dowd (1976).

My preliminary testing suggests corn and sorghum are reasonably compatible with mature alfalfa, bird's-foot trefoil, crown vetch and Dutch white clover. However, in many cases I find the ground cover must be well established before intercropping the grain. Interplanting a ground cover and a large grain in the same year often leads to poor establishment or failure of the ground cover. Perhaps some of the mature domestic annuals exert an alleleopathic influence on the young domestic perennials, in a manner similar to that described by Wilson (1968) for the succession of old fields back to tallgrass prairie. Whittaker and Feeny (1971) offer a comprehensive view of the diversity of allelochemic reactions and an interesting overview of its potential role in the evolution of species.

The vast combination of variables (soils, plant varieties and density, management practices, weather) assure that a wide range of experimental results would be obtained. While the first two approximations may offer some degree of success, it is unlikely that the prairie analogue could be carried much further within the present socio-economic framework of corn belt agriculture. The ecological awareness of recent years has evolved a popular dogma that increased diversity means increased stability (Odum 1969, Margalef 1963) and one may be tempted to work towards the intercropping of dozens of plant species. The diversity dogma, while true in a general way, has now been challenged from at least four different directions (Ehrenfeld 1976) and perhaps a more tempered view is "that a little powerful diversity of the right kind is a key component of stability " (Atsatt and O'Dowd 1976). Increasing the ground cover beyond one or two major components would probably leave so little niche space for a grain crop that the planting would be suitable only for a forage/hay/silage economy.

It is improbable that during the coming decades energy supplies will be so expensive or so scarce that the corn belt will shift entirely away from its present mixed hay-grain economy. However, if energy costs (especially in the form of fertilizer) continue to generally increase (especially as natural gas is deregulated) the proportions could shift toward more hay and less grain. With grain exports and prices increasing in the last few years the shift towards feeding less grain and more forage to livestock is already underway (Hodgson 1976). Such exports have been encouraged at the federal level to help offset the deficit in our balance of payments created by increasing energy imports. Part of this energy goes back into agriculture and may help accelerate the forage demand for livestock. One way of balancing the mix with minimum energy input and minimum soil losses may be the development of partial prairie analogues along the lines suggested in this paper.

The plantings which have lead me to offer these notions have thus far been too small, too few, and too poorly controlled to provide reliable data. Considerable research (by others) has gone into practices variously labeled minimum-tillage, zero tillage, stubble mulching, strip tillage, sod tillage, and sod intercropping, but to date I have located no serious research on repeatedly intercropping grains within perennial harvestable ground covers. There appears to be considerable opportunity and incentive for further study.

LITERATURE CITED

Alexander, J. D., Fehrenbacher, J. B., and Ray, B. W. 1968. Characteristics of dark colored soils under prairie in a toposequence in southwestern Illinois. Proc. Symp. Prairie Restoration, Knox Coll. Biol. Field Sta. Spec. Pub. No. 3:38.

Atsatt, P. R., and O'Dowd, D. J. 1976. Plant defence guilds. Science 193:24-29.

Beasley, R. P. 1972. Erosion and sediment pollution control. Iowa State Univ. Press, Ames.

Cawley, J. F., R. C. Burruss, and H. D. Holland. 1971. Chemical weathering in central Iceland. An analog of pre-Silurian weathering. Science 165:391-392.

Cleaves, E. T., A. E. Godfrey, and O. P. Bricker. 1970. Geochemical balance of a small watershed and its geomorphic implications. Bull. Geol. Soc. Amer. 81:3013-3032.

Cody, M. L. 1974. Optimization in ecology. Science 183:1156-1164.

Coffman, B. 1971. Newest findings on fertilizer runoff. Farm Journal, August 1971:21-22.

Comptroller General of the U.S. 1977. To protect tomorrow's food supply, soil conservation needs priority attention. Government Accounting Office, Report to Congress, CED-77-30.

Dale, C. 1976. Farm column. Iowa City Press Citizen, Wed., July 7, 1976:3D.

Ellison, W. D. 1948. Erosion by raindrop. Sci. Amer., Nov. 1948. No. 817:1-7.

Ehrenfeld, D. W. 1976. The conservation of non-resources. Amer. Sci. 64:648-656.

Hadwiger, D. F. 1975. The Green Revolution: Some new perspectives. Change Mag. 7(9):36-41, 62.

Hodgson, H. J. 1976. Forage crops. Sci. Amer. 234 (2):60-75.

Kohl, D. H., G. B. Shearer, and B. Commoner. 1971. Fertilizer nitrogen: Contribution to nitrate in surface water in a corn belt watershed. Science 174:1331-1334.

Lee, D. H. K. 1970. Nitrates, nitrites and methemoglobinemia. Environ. Res. 3:484-511.

Lockeretz, W., et al. 1975. A comparison of the production, economic returns and energy intensiveness of corn belt farms that do and do not use inorganic fertilizers and pesticides. Center for the Biology of Natural Systems, Washington University, St. Louis, Missouri.

Magee, P. 1973. Nitrosamines: Ubiquitous carcinogens? New Scientist 59:432-434.

Margalef, R. 1963. On certain unifying principles in ecology. Amer. Nat. 97:357-374.

Meinzer, O. E. 1927. Plants as indicators of groundwater. U.S. Geol. Surv. Water Supply Pap. 577. 54 p.

Miller, J. 1973. Genetic erosion: Crop plants threatened by government neglect. Science 182: 1231-1233.

Neumann, A. M. 1974. Factors influencing the conversion of forest soils to Mollisols in the prairie peninsula. Abst. Amer. Quat. Assoc., Third biennial meeting:52.

Odum, E. P. 1969. The strategy of ecosytem development. Sceince 164:262-270.

Paul, E. A. 1969. Characterization and turnover rate of soil humic constituents. in: S. Pawluk, ed. Pedology and quaternary research. Symposium at Edmonton, Alberta. pp. 63-76.

Perelman, M. J. 1972. Farming with petroleum. Environment. No 8:8-13.

Pimental, D., L. E. Hurd, A. C. Bellotti, M. J. Forster, I. N. Oka, O. D. Sholes, and R. J. Whitman. 1973. Food production and the energy crisis. Science 182:443-449.

Phillips, D. A., J. G. Torrey, and R. H. Burris. 1971. Extending symbiotic nitrogen fixation to increase man's food supply. Science 174:169-171.

Quniby, J. R., and Marion, P. T. 1962. Sorghum for forage. In: H. D. Hughes, M. E. Heath, and D. S. Metcalfe, eds. Forages - The science of grassland agriculture. 2nd ed., Iowa State Univ. Press, Ames, pp. 346-356.

Rappaport, R. A. 1971. The flow of energy in an agricultural society. In: Energy and power, Freeman, San Francisco, pp. 69-82.

Robinson, W. T. 1958. Phreatophytes. U.S. Geol. Surv. Water Supply Pap. 1423:16-22.

Sanders, L. O. 1971. Common compounds linked to cancer. Jour. Amer. Med. Assoc. 216(7):1006-1008.

Sandler, N. D. 1976. Farm news column: Cedar Rapids Gazette, July 20:12.

Smith, R. L., J. H. Bouton, S. C. Shank, K. H. Queensberry, M. E. Tyler, J. R. Milam, M. H. Gaskins, and R. C. Littell. 1976. Nitrogen fixation in grasses inoculated with Spirillum lipoferum. Science 193:1003-1005.

U.S.D.A. 1960. Growing grain sorghum. U.S.D.A. Leaflet No. 478:8.

U.S.D.A. 1968. A national program of research for environmental quality pollution in relation to agriculture and forestry. U.S.D.A. Agriculture Research Program Development and Evaluation Staff, Wash. D.C.

U.S. Geological Survey. 1972. Erosion and sediment descriptive brochure. Super. Doc., Gov. Print. Off.

vandenBosch, R. 1972. The cost of poisons. Environment 7:18-32.

Van Doren, C. A., and Hays, O. E. 1958. Interseeding legumes in corn. U.S. Dept. Agr. Leaflet No. 433. 3p.

Wade, N. 1972. A message from corn blight. The dangers of uniformity. Science 177:678-679.

Wade, N. 1973. Agriculture: NAS panel charges inept management, poor research. Science 179: 45-47.

Weaver, J. E., and Harmon, G. W. 1935. Quantity of living plant materials in prairie soils in relation to run-off and soil erosion. Conservation and Survey Division, University of Nebraska, Bulletin 8. 7 p.

White, W. N. 1932. A method of estimating groundwater supplies based on discharge by plants and evaporation from soil. U.S. Geol. Survey Water Supply Pap. 659-A.

Whittaker, R. H., and Feeny, P. P. 1971. Allelochemics: Chemical interactions between species. Science 171:757-770.

Wilson, R. E. 1968. The role of allelopathy in old-field succession in grassland areas of central Oklahoma. Proc. Symp. Prairie and Prairie Restoration. Knox. Coll. Biol. Field Stat. Spec. Pub. No. 3:24-25.