CONSERVATION IN HIGHLY FRAGMENTED LANDSCAPES

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The Tallgrass Prairie Mosaic

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Introduction

Grasslands are biological communities in which the landscape is dominated by herbaceous vegetation, especially grasses: they contain few trees or shrubs. An estimated 16 to 40% of the world's land surface is, or was, covered by grasslands (Singh et al. 1983, Burton et al. 1988, Groombridge 1992). Area estimates of current savanna and temperate grasslands are from 16.1% to 23.7% of the world's land area (Groombridge 1992). Notable examples include prairies of North America, llanos of northern South America, cerrados and campos of Brazil, pampas of Argentina, steppes of central Asia, veldt and savannas of Africa, and grasslands of Australia. Grasslands are the largest vegetational unit in North America, covering approximately 20% of the land area, and prairies are the most abundant type of grassland on the continent (Küchler 1964, Risser et al. 1981, Burton et al. 1988). Prior to European settlement, prairies occupied a more or less continuous (except at the fringes), roughly triangular shaped area covering 3.6 million square km. The base extended for 3,900 km along the foothills of the Rocky Mountains from the Canadian provinces of Saskatchewan and Manitoba southward through New Mexico into Texas (Figure 3.1). The apex of the triangle, the prairie peninsula (Transeau 1935), extended 1,600 km eastward into the Midwest and included the prairies of Illinois, Iowa, Indiana, Minnesota, Missouri, and Wisconsin, with scattered outliers in southern Michigan, Ohio, southwestern Ontario, and Kentucky (Risser et al. 1981; Madson 1982; Farney 1980; Weaver 1954, 1968; Whitney and Steiger 1985) (Figure 3.1). This chapter focuses on this eastward projection of tallgrass prairie around what is known as the *prairie peninsula* (Transeau 1935).

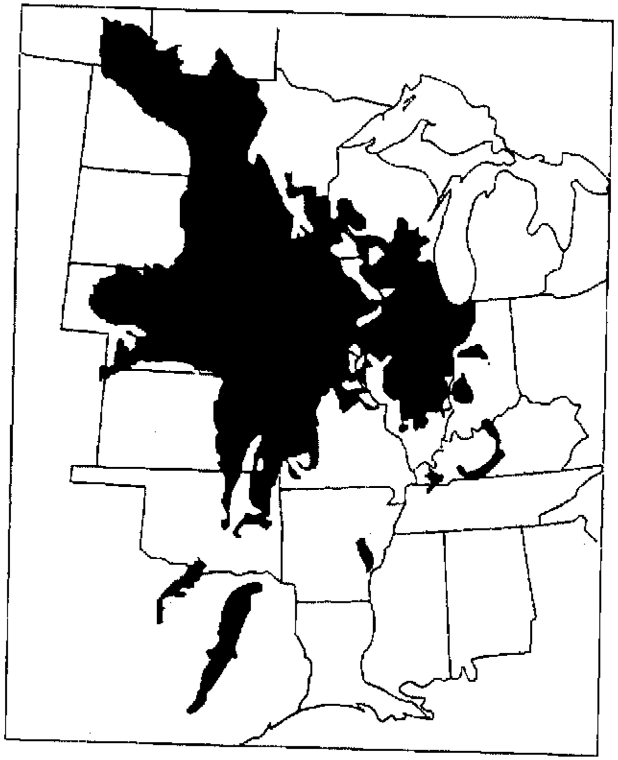

Figure 3.1. Distribution of the tallgrass prairie ecosystem prior to European settlement.
Adapted from Anderson 1991

The Prairie Biome

Prairies are complex ecosystems in which plants, browsing and burrowing mammals, insects and other organisms, fire, and climate interact. In agricultural terms, the tallgrass prairie sustains high productivity while building and maintaining soil (Chapman et al. 1990). Prairies developed and were maintained under the influence of three major disturbance factors: aridity with periodic drought, fire, and grazing (Anderson 1982, 1990, 1991).

Occurring primarily in the central portion of North America, prairies are subject to a continental climate with wide seasonal variability in temperatures—hot summers and severely cold winters. Because of the rain shadow effect of the Rocky Mountains, which intercepts the eastward flow of moist air from the Pacific Ocean, there is a gradual increase in average annual precipitation from west to east, and this is reflected in dominant species and the types of prairies

found in central North America (King 1981a,b). From west to east within the central grasslands, average annual precipitation increases from 25–38 cm to 75–100 cm and becomes more reliable, potential evapotranspiration decreases, the number of days with rainfall increases, and periods of low humidity and periodic droughts in July and August decrease (Risser et al. 1981). Droughts, characteristic of North American prairie, may last only one or two months or continue for several years. Based on a study of tree rings, Blasing and Duvick (1984) concluded that severe droughts occurred in the decades of the 1930s, 1890s, 1820s, and 1700s. During severe dry spells, drought-tolerant species shifted their geographical ranges eastward, replacing drought-sensitive species that became locally extirpated, and shifted back as rainfall patterns changed and individual droughts ended (Weaver 1968).

Most ecologists believe that prairie vegetation in the midwestern United States would have largely disappeared during the past 5,000 years had it not been for periodic burning. Presettlement fire return intervals are estimated to have been one to five years (McClain and Elzinga 1994). These fires moved rapidly across the prairie, and damaging heat from the fires did not penetrate the soil more than a few mm below the surface (Anderson 1982, 1990). While a few wildfires were undoubtedly started by lightning, most fires were deliberately set by Native Americans (Moore 1972, Higgins 1986, McClain and Elzinga 1994, White 1995). The role of Native Americans in maintaining the prairies and the reasons they burned these grasslands have been discussed and documented by various authors (e.g., Stewart 1951, 1956; Curtis 1959; Pyne 1986).

Grazing also played a major role in forming the structure of prairies. Grasses generally produce more biomass annually than can be decomposed in a year. This production of excess herbage probably evolved in response to grazing; however, the productivity of grasslands declines when excess plant litter is not removed by fire or grazing (Golley and Golley 1972, Knapp and Seastedt 1986). A considerable portion of the above-ground biomass of a prairie was consumed each year by the grazing of a wide range of browsing animals, such as bison, elk, deer, rabbits, and grasshoppers (Risser et al. 1981). Bison graze selectively both spatially and temporally (Vinton et al. 1993). When conditions are favorable, bison consume grasses almost exclusively. Burning favors grasses; hence, bison use burned areas more than unburned (Fahnestock and Knapp 1993). Grazing by bison and fire interact in determining plant community composition (Vinton et al. 1993).

Deer, on the other hand, browse on prairie forbs rather than grasses. The forb species browsed by deer vary seasonally and from year to year, and deer browsing intensity on forbs varies seasonally, being highest in early to mid-July (Anderson et al. 1995; Anderson, this volume). Deer consume a large portion of the vegetative mass of the plants they browse, and deer browsing can cause a significant reduction in the reproductive output of some forb species. The great wave of late Pleistocene-early Holocene extinction of 35–40 species of large mammals, many herbivorous, from North America occurred before the formation of the tallgrass prairie (Graham et al. 1987, Pielou 1991).

Finally, activities by animals created disturbance patches within prairies. Bison or buffalo wallows can be quite large—several meters to 45 m in diameter (Polley and Collins 1984), and they can persist, used and unused, for many years. Other disturbances were made by smaller mammals, such as badgers, pocket gophers, and prairie voles, as well as arthropods, such as ants (Gibson 1989, Gibson et al. 1990, Platt and Weis 1977, Reichman et al. 1993). Trampling by bison, as well as cattle, also created small open areas. These disturbances added to species richness and spatial heterogeneity in tallgrass prairies. The plant species most often associated with disturbed sites in prairies are pioneer species and include a number of annuals (otherwise rare in tallgrass prairie) as well as perennials. Some species have subsequently become troublesome agricultural weeds. Havercamp and Whitney (1983) classified prairie forbs into three categories: indicator species, modal species (species that have their maximum presence value in prairies), and weedy species.

Thus, grasslands evolved under conditions of periodic drought, fire, and grazing and are adapted to all three (Owen and Wiegert 1981; McNaughton 1979, 1984; Anderson 1990). Prairie plants thrive under these conditions largely by being herbaceous perennials with underground storage/perennating structures, growing points slightly below ground level, and extensive, deep root systems. The three factors of periodic drought, grazing, and fire are important to keep in mind when formulating management practices for today's prairie remnants. In later discussions in this chapter, grazing is mentioned as being a disturbance factor in prairie remnants, but this refers only to grazing by domestic livestock, which has a quite different impact than the free-ranging grazing of native large mammals, such as bison.

Although many woody species, for example, oaks (*Quercus* spp.), readily resprout after being top-killed by fire, prairie species are generally better adapted to burning than are most woody plants. The adaptation that protects grasses and forbs from fire is their herbaceous growth habit: the plant dies back to its underground organs each year, exposing only dead material above ground (Gleason 1922a). While prairie fires are very hot above ground (up to 680°C—Wright 1974; Rice and Parenti 1978), they move quickly and soil is a good insulator, thus little heat penetrates the soil. The same adaptation that protects prairie plants from fire also protects them from drought and grazing. Growing points beneath the surface of the soil permit regrowth after intense grazing and protect perennating organs from desiccation during periods of drought or from fire at any time of the year (Gleason 1922a; Tainton and Mentis 1984; Anderson 1982, 1990).

The grasslands of North America originated in the Miocene-Pliocene transition, about 7–5 million years before the present (B.P.) in association with the beginning of a global drying trend. In addition, the uplift of the Rocky Mountains created

a partial barrier between moist Pacific air masses and the interior portion of the continent. Woody plants are generally less well adapted to drought than most grass species, and the spread of grasslands occurred at the expense of forests. As the grassland expanded, numbers of grazing and browsing animals increased, an indication that the association of grasses and grazers occurred over a long period of time (Stebbins 1981, Axelrod 1985, Webb et al. 1983).

Ecologists traditionally have separated the central grassland into three major west-east divisions: an arid western grass prairie, an intermediate mixed grass prairie, and a relatively moist eastern tallgrass prairie. The dominant grasses of the eastern tallgrass prairie, the focus of this chapter, are big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*)—grasses that reach heights of 1.8 to 3.6m—on mesic tallgrass prairie sites; prairie cordgrass (*Spartina pectinata*) and bluejoint grass (*Calamagrostis canadensis*) on wet prairies; and little bluestem (*Schizacharyum scoparium*) and sideoats grama (*Bouteloua curtipendula*) on dry sites (Figure 3.2. Weaver 1954, Risser et al. 1981, Parrish and Bazzaz 1982, Umbanhowar 1992). The eastern tallgrass prairie was formed following the most recent period of the Pleistocene glaciation (Axelrod 1985). Based on the evidence of fossil pollen grains, tallgrass prairie pushed east of the Mississippi River about 8,300 years ago (King 1981a,b). As the last of the most recent ice sheet retreated, mesic deciduous forests dominated most of the midwestern landscape. A drying and warming trend began about 8700–7900 B.P., and prairie began to replace deciduous forests in the Midwest. Prairie maximized its eastern extent during the Hypsithermal Period (8000–6000 B.P.), which was the hottest and driest part of the Holocene (Pielou 1991), and much of the prairie persisted as the climate became cooler and moister following the Hypsithermal.

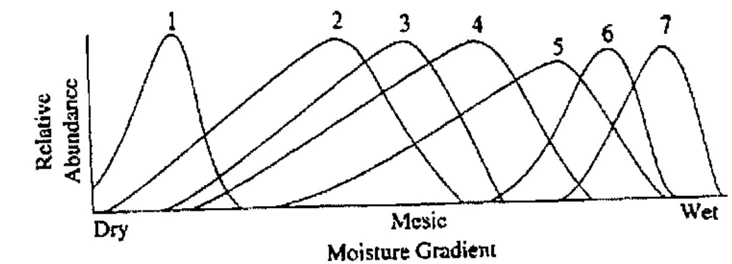

Figure 3.2. Generalized distribution of major grass species across a soil moisture gradient: (1) sideoats grama (*Bouteloua curtipendula*); (2) little bluestem (*Schizachyrium scoparium*); (3) Indian grass (*Sorghastrum nutans*); (4) big bluestem (*Andropogon gerardii*); (5) switchgrass (*Panicum virgatum*); (6) bluejoint grass (*Calamagrostis canadensis*); (7) prairie cordgrass (*Spartina pectinata*).

Adapted from Anderson 1991

The Tallgrass Prairie Mosaic

While the prairie biome was nearly continuous (except at the fringes), it was by no means homogeneous. Prior to European settlement, the landscape of the tallgrass prairie was a complex matrix with specialized communities embedded in the prairie—fens, pannes, sedge meadows, marshes, ponds, kames, sand blowouts, savannas, and prairie groves. Prairie occurs in both glaciated and unglaciated areas, and there is much variation in soil particle size, heterogeneity, texture, organic content, and pH. Some prairies occur where there are outcrops of sandstone, limestone, dolomite, quartzite and chert. All of these foster variation in biotic communities and determine what prairie species occur at a particular place at a particular time. Overlaying this local variation in soils and topography onto a continental moisture gradient in the lee of the rainshadow of the Rocky Mountains, it becomes difficult to divide the long prairie continuum into discrete units of classification.

Prior to European settlement, the vegetation of much of the Midwest was a shifting mosaic of prairie, forest, savanna, and wetlands that was largely controlled by the frequency of fire under climatic conditions that were capable of supporting any of these vegetation types (Gleason 1913, Grimm 1983). The frequency of fire, and hence the distribution of prairie, was largely determined by topography and the occurrence of natural firebreaks (e.g., rivers, streams, and wetlands). Fires carry readily across level to gently rolling landscapes, but is patchy in hilly and dissected landscapes (Wells 1970; Grimm 1984). Fire tends to carry well uphill because rising convection currents encourage its spread. But as fire moves down slopes, the convection currents tend to retard it by rising upward and working against the downward direction of the moving fire. The importance of waterways in determining the distribution of forest and prairie prior to European presettlement was demonstrated for Illinois by Gleason (1913) and Minnesota (Grimm 1983) through the use of the Government Land Office Records. Both authors found that prairies were associated with the west sides of streams and other natural firebreaks. Gleason (1913) attributed this pattern to prevailing westerly winds that carried fires from west to east; the west sides of waterways, therefore, burned more frequently than the east sides.

Using a map showing the distribution of prairies and timber (forest and savanna) for Illinois, based on the Government Land Office Records (Anderson 1970), and a map of the average slope range for the state (Fehrenbacher et al. 1968), Anderson (1991) determined the simultaneous occurrence of slope categories and vegetation. Most of the prairie vegetation (82.3%) occurred on landscapes with slopes of 2–4%; only 23.0% of the timbered land, usually on floodplains, was associated with this slope category. In contrast, 77% of the timbered land occurred on sites that had slopes greater than 4% (4–7% slope = 35.2% timber and >7% slope = 41.8% timber—Figure 3.3). Iverson (1988) also showed that presettlement forests were positively correlated with sloping landscapes.

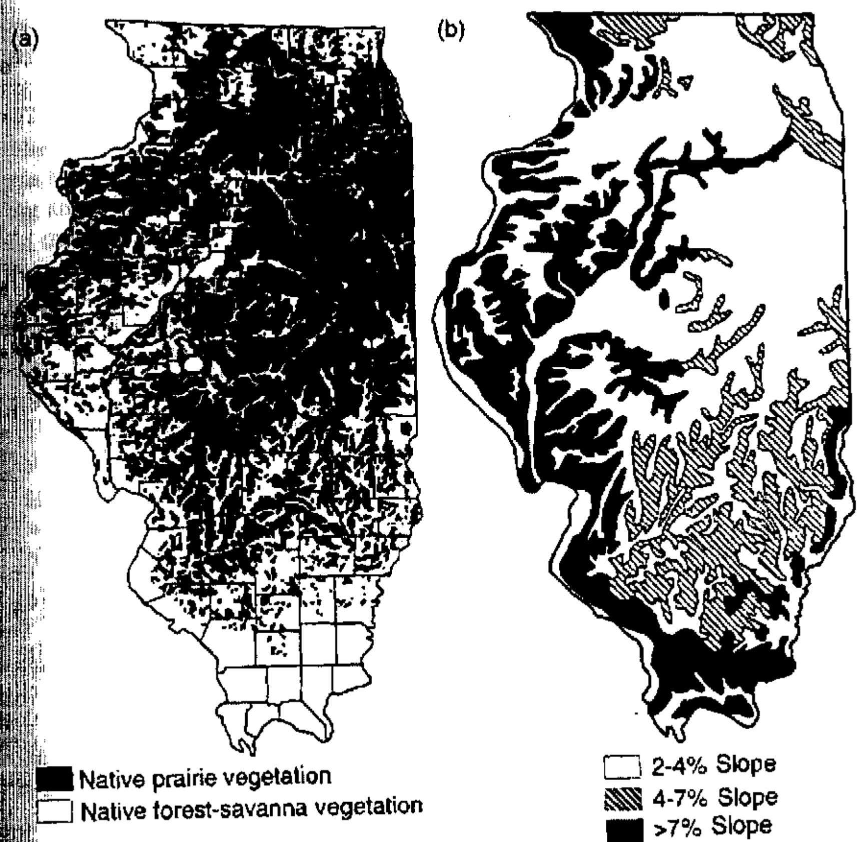

Figure 3.3. The distribution of native forest-savanna vegetation and prairie (a) compared to average slope categories (b) in Illinois.

A number of different classification schemes have been developed to categorize the great variety found in the tallgrass prairie. The systems used in three states are shown in Table 3.1. All three are based on natural community classification. The systems for Illinois and Missouri use soil/substrate as the primary unit and are similar, differing primarily to account for differences in the natural landscape of the states. The scheme for Minnesota is based primarily on water regimes. The Nature Conservancy classification system describes four main types of tallgrass prairie, based primarily on geologic history: Lake Agassiz type, Central Midwest type, Glaciated Lower Midwest type, and Unglaciated Lower Midwest type (Chapman et al. 1990). Often available soil moisture is used to delineate five moisture categories: wet, wet-mesic, mesic, mesic-dry, and dry (Curtis 1959). The moisture categories are often used with other descriptions, e.g., *wet-mesic*

Table 3.1. Comparisons of prairie classifications for three midwestern States. Sources of data: Illinois (White 1978), Missouri (Nelson 1985), and Minnesota (Aaseng et al. 1993).

Illinois	Missouri	Minnesota
(Blacksoil) prairie	(Blacksoil) prairie	Upland prairie
5 moisture categories	5 moisture categories	mesic
		dry
Sand prairie	Limestone/Dolomite prairie	barrens subtype
5 moisture categories	2 moisture categories	sand-gravel subtype
		hill subtype
Gravel prairie	Chert prairie	bedrock bluff subtype
3 moisture categories	2 moisture categories	
Dolomite prairie	Sandstone/Shale prairie	Wet prairie
5 moisture categories	2 moisture categories	
Hill prairie	Sand prairie	
4 substrate categories	2 moisture categories	
Shrub prairie	Handpan prairie	

sand prairie. Today, when used alone these generally refer to "blacksoil" or "typical" prairies of the region that have fine-textured, deep soils derived from loess or glacial till, although some may occur on alluvium (White 1978).

The number of species that occupy a prairie is rather high for a temperate ecosystem. For example, inventories of vascular plants occurring in small (ca. five acre) black-soil prairie remnants typically exceed 100 native species (Robertson unpublished data, Illinois Nature Preserves Commission unpublished data, Robertson et al. 1983). Weaver (1954) placed prairie plants into four phenological categories: prevernal, vernal, aestival, and autumnal. The first two are low in stature and generally die back to the ground after setting seeds. As the season progresses into summer and fall, the plants become progressively taller. The early season grasses generally have the C_3 photosynthetic pathway, while later species are C_4. A useful phenology chart is included in Kirt (1995).

Parish and Bazzaz (1982) propose that coexistence of species in grasslands occurs by (1) alpha-niche differentiation involving coevolution or pre-adaptation to reduce competition for resources among plants sharing the same location, i.e., staggered timing of growth and reproduction or stratification; (2) niche separation on the beta-scale, i.e., among habitats within a landscape, which is governed principally by available soil moisture; and (3) regeneration characteristics that enable species to become established on disturbed sites (Burton et al. 1988).

Original Extent and Recent Loss of Prairie in Midwest

Midwestern prairies, as defined in the context of this book, are all within the tallgrass prairie peninsula region and bounded on the north, east, and south by

regions of deciduous forest (Transeau 1935). The original extent of the tallgrass prairie in six midwestern states is given in Table 3.2. At the west end of the region prior to European settlement, prairie occupied about 85% of the land area (12 million ha) of Iowa, and just over 60% (8.5 million ha) of Illinois was tallgrass prairie. Toward the east the tallgrass prairie became patchy, barely reaching Ohio (Lafferty 1979) and Ontario (Bakowsky and Riley 1994), occupying about 2.5% of the land area of each. Most of these area estimates are based on the original land surveys and, unfortunately, surveyors did not consistently distinguish prairie from some types of savannas or open wetlands such as sedge meadows and fens.

The loss of eastern tallgrass prairie has been nearly complete. The Nature Conservancy (Chapman et al. 1990) estimates that more than 99% of the tallgrass prairie east and north of the Missouri River has been destroyed, and only about 15% remains to the west and south of this river. Klopatek et al. (1979) estimated the amount of remaining intact natural habitats and ranked the three states in the heart of the prairie peninsula (Indiana, Illinois, and Iowa) as 48–50th respectively. Further, remaining high-quality prairies tend to be found in very small patches. Of the 253 prairie sites identified as grade A or B by the Illinois Natural Areas Inventory, 83% are smaller than ten acres and 30% are less than one acre (Figure 3.4). Three examples from Illinois counties illustrate these drastic changes in tallgrass prairie: 158 ha (0.07%) of 211,200 ha, 2 ha (<0.0007%) of 271,100 ha, and 0.4 ha (0.0002%) of 239,700 ha of high-quality remnant prairies remain in Cook, McLean, and Champaign counties, respectively. Using this kind of information, Noss et al. (1995) categorized the tallgrass prairie east of the Missouri as a critically endangered ecosystem.

This staggering amount of habitat loss occurred in an astonishingly short period, roughly between 1840 and 1900. European settlers, emigrating from

Table 3.2. Original extent of the tallgrass prairie and present day remnants for six states in the upper Midwest.

State	Acres of prairie prior to European settlement	% of natural vegetation in prairie	Acres of prairie remaining	% of original prairie remaining
Illinois	21,000,000	60%	2,300	0.01%
Indiana	3,000,000	13%	1,643	0.055%
Iowa	30,000,000	85%	30,000	0.1%
Minnesota	18,000,000	36%	75,000	0.4%
Missouri	15,000,000	34%	70,000	0.47%
Wisconsin	2,100,000	5.5%	2,111	0.1%

Sources of data: Illinois (Anderson 1970, Schwegman 1973, White 1978), Indiana (John Bacone and Robert Petty, Wabash College, via John Bacone), Iowa (Smith and Jacobs 1992, Thompson 1992), Minnesota (Wendt 1984; Robert Dana, personal communication, Aug 1995), Missouri (Greg Gremaud, personal communication, Aug 1995; Nelson 1985, Schroeder 1981), Wisconsin (Eric Epstein, personal communication, Aug 1995).

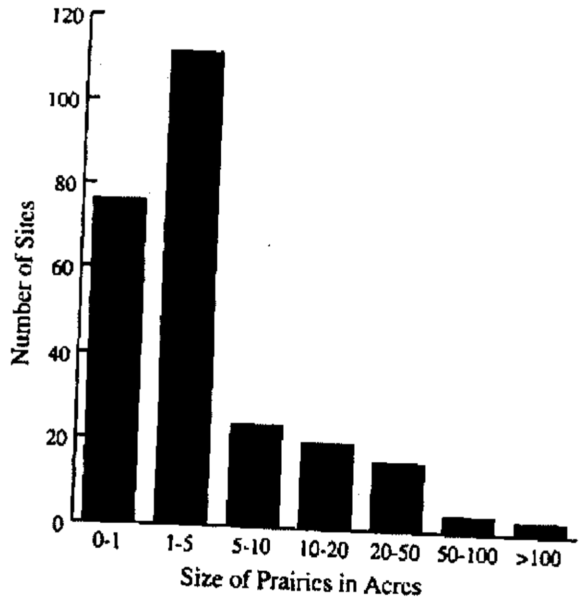

Figure 3.4. Number of grades A and B (high quality) prairies remaining in Illinois classified by size category.

(White 1978) Database updated by the IL Department of Natural Resources, Springfield, Ill

forested regions in Europe and eastern North America, found the prairies to be inhospitable due to the hordes of insects, intense summer heat and high humidity, bleak winters, and periodic fires. As the settlers migrated, they followed the finger-like traces of forest along the major waterways and initially avoided the larger tracts of prairie. Timber was considered such an important commodity on the prairie that counties were not allowed to form as governmental units until residents could demonstrate that they had access to sufficient timber to support development (Prince and Burnham 1908). Another difficulty with settling the prairie was that the prairie sod was deep and dense with tangled roots. Prairie sod could not be broken easily until 1837, when John Deere invented the self-scouring, steel-bladed plow. Finally, many larger tracts of prairie remained unsettled because of the lack of transportation to get crops to distant markets. With the coming of the railroads in the 1850s and 1860s, however, prairies were rapidly converted to cropland (Anderson 1970). Page and Jeffords (1991) estimated that 3.3% of the prairies in Illinois were plowed each year during this period. In Iowa, nearly 12 million ha of prairie was converted to agriculture between 1850 and 1930, for an average of 150,000 ha per year (Thompson 1992). Robert Ridgway (1889), the noted pioneer of ornithology in Illinois, related that in 1871 Fox Prairie (Richland County, Illinois) was a large rolling plain of uninterrupted prairie 10 km by 16 km (16,000 ha), but that by 1883 only 65 ha (0.4%) remained.

prairies were converted to agriculture, landscape-scale fires, which had nearly annually across the prairie in presettlement times, were actively by settlers who viewed them as a threat to economic security. Cessation furthered the demise of the prairies as many remaining sites were converted or savannas by invading tree species. Mesic black-soil prairies continued in unplowed cemeteries and along railroad rights-of-way. Railroad of-way, extending at least 30 m on either side of the track, were established to prairie conversion, fenced to keep out livestock, and often managed with those fires, along with many accidental fires, prevented the invasion of species and exotic weeds. In the last 20 to 30 years, however, many remnant prairies along railroads have disappeared because of railroad onment and subsequent habitat conversion or herbicide use to manage of-way. Thus, a fully functional tallgrass prairie ecosystem in the Midwest a historic phenomenon. Existing remnants lack the full complement of processes that operate at large scales (e.g., landscape fires, large grazing mals, top predators, or interaction with adjacent natural habitats).

...act of Habitat Loss on Biodiversity

tallgrass prairie has been called "the most diverse repository of species in Midwest [and] . . . habitat for some of the Midwest's rarest species" (Chapman al. 1990). It is difficult to give a total number of species that occur in the grass prairie. While many species maximize their frequency of occurrence in airies, few species are endemic in the tallgrass prairie ecosystem. For this discussion we define all species that occupy or utilize the types of habitats nerally recognized as prairie by natural community classifications of midwest-states as prairie species. Excluded are species restricted to savannas and open ass, sedge, and forb-dominated communities classified as wetlands, such as ge meadows and fens.

...ants

Using various sources, Widrlechner (1989) compiled a list of 862 species of plants native to prairies of the midwestern United States. Similarly, the Illinois Plant Information Network (ILPIN), a computerized database listing life history, habitat, taxonomic, and distributional information available on the vascular flora of Illinois (Iverson 1992), records 851 species of plants native to Illinois prairies. A general pattern of increasing diversity with size of a habitat patch, referred to as the species/area curve, is commonly observed across a wide range of taxonomic groups and habitat types (Gleason 1992b, MacArthur and Wilson 1967, Simberloff and Gotelli 1984). The species/area curve observed in the flora of prairies suggests that even very small patches, as small as 4 ha, contain most of the local diversity of plants likely to be found on prairies of a much larger size, approximately 100 species (Figure 3.5). Unfortunately, few remaining prairies (e.g., <17% of high-quality prairies in Illinois—Figure 3.4) are above this size threshold. A total of approximately 140 species of native prairie plants occur in three blacksoil prairie remnant nature preserves (Loda, Prospect, and Weston, each about 2 ha) in central Illinois (Robertson, unpublished data). Each prairie individually has 85–90 native species, but the combined total gives a reasonable approximation of the level of plant diversity that might have been observed in large tracts of mesic prairie prior to European settlement. Most plant species are infrequently encountered on individual prairie sites, as demonstrated by two floristic surveys of small prairie fragments in Illinois and Indiana (Betz and Lamp 1989, 1992). In both studies, most species were found in fewer than four sites (Figure 3.6). Therefore, the complement of species found on any given prairie remnant is likely to be individualized and somewhat unique. Any further loss of prairie fragments represents the potential for a serious erosion of the floristic diversity of the state because of the relatively few good habitat patches in which many of these species are currently found. Nonetheless, it is notable that few of the plant species that occur on midwestern tallgrass prairies are so rare as to merit attention on the federal endangered species lists (Taft 1995).

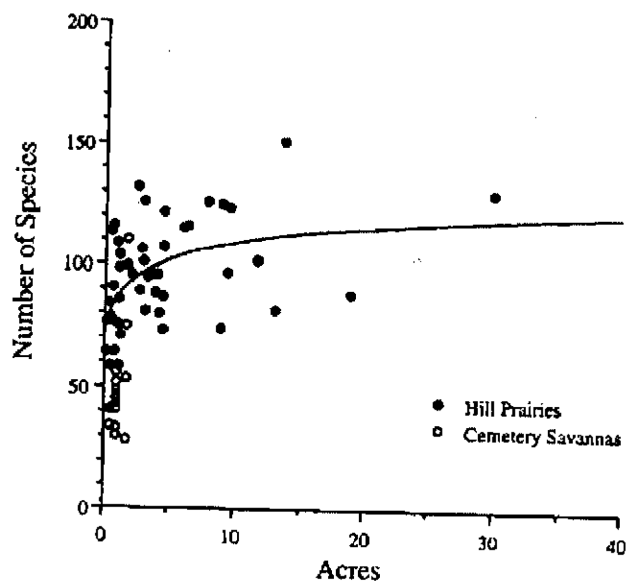

Figure 3.5. Number of plant species censused in prairie remnants of various sizes demonstrating that diversity of prairies increases with size.

Data are from Evers (unpublished data on file at the Illinois Natural History Survey) and Betz and Lamp (1989, 1992)

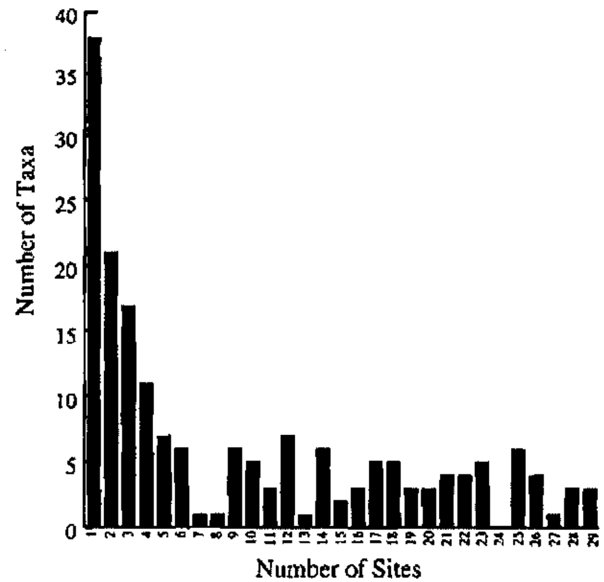

Figure 3.6. Number of sites in which each of 180 native taxa of plants were found in a survey of 29 remnant black soil prairies in Illinois and Indiana.

Data from Betz and Lamp (1989)

Birds

As one might expect, the dramatic change in the landscape after European settlement resulted in equally dramatic changes in bird populations. Several Illinois bird population studies, beginning in the mid-1800s and continuing through 1989, have provided insight into these changes. At first the change from prairie to agricultural land caused an increase in several bird species with the formation of secondary grasslands such as pastures and hayfields. These secondary grassland habitats became acceptable breeding grounds for a majority of prairie birds (Graber and Graber 1963). The prairie chicken especially benefited from this new combination of food and cover as well as the decrease in animal predators. It is thought that the dickcissel preferred secondary grasslands over original prairie (Kendeigh 1941, Graber and Graber 1963, Zimmerman 1971). Despite increased populations of some prairie birds throughout Illinois, however, Graber and Graber (1963) found that population changes were negligible for most species between 1909 and 1956.

Nevertheless, many birds considered very common prior to 1900 decreased during this century (Herkert 1991b). The most dramatic decline in almost all prairie bird populations in Illinois occurred from 1967 to 1989 (United States

Fish and Wildlife Services breeding bird survey, unpublished data—Table 3.3). Although the cause of this recent decline is not fully known, it is thought to be related to the rapid conversion of grazing lands to either crops or forest. A decrease in hay production coupled with pasture reduction has resulted in a loss of secondary grasslands on top of the depletion of the original prairie. This overall loss of grassland habitats is partially responsible for the current fragmented landscape. A reduction in available habitat results in a reduction of individuals, local populations, or perhaps even species. Less obvious, but also important to breeding birds, is that smaller habitats may lack essential resources and provide less of a buffer in the event of natural catastrophes or predation. Although only three species of prairie birds have been eliminated from Illinois, 13 more species are considered threatened or endangered, mainly because of habitat loss (Herkert 1991a,b).

One of the birds included on the endangered species list has experienced an enormous decline in numbers due more to the invasion of its habitat by a non-native species than to a reduction of habitat. In 1860, the state of Illinois was home to 10 million greater prairie chickens (Westemeier 1983, Westemeier 1990, Westemeier and Edwards 1987), a species that had survived in large numbers over several thousand years despite native predators such as coyotes, skunks, and opossums. Although much of the prairie was gone by 1912, prairie chickens

Table 3.3. Relative abundance (A = abundant; VC = very common; C = common) of several prairie bird species in Illinois before 1900 and changes in species populations from 1967 to 1989.

Species	Prior to 1900	1967–1989
Eastern meadowlark	A	−67.0
Dickcissel	A	−46.0
Grasshopper sparrow	A	−56.0
Bobolink	A	−90.4
Henslow's sparrow	A	——[1]
Red-winged blackbird	VC	−18.8
Greater prairie chicken	VC	——[1]
Upland sandpiper	VC	−16.8
Vesper sparrow	C	+12.1
Horned lark	C	0.0
Field sparrow	C	−52.6
Song sparrow	C	−29.3
Savannah sparrow	C	−58.4
American goldfinch	C	−42.8
Common yellowthroat	C	−8.8
Sedge wren	C	−22.5

[1]Too sparse throughout period to determine a trend.

Data prior to 1900 are based on the work of Nelson (1876) and Ridgway (1889, 1895). Population changes from 1967 to 1989 are based on U.S. Fish and Wildlife Service breeding bird survey data as tabulated by Herkert (1991b).

still occupied 92 counties but quickly decreased in numbers with the release and establishment of ring-necked pheasants (Westemeier 1983). Since 1989, there have been fewer than 100 prairie chickens in Illinois (Ron Westemeier, personal communication May 1994). Sanctuaries were established around the state to ensure that suitable habitat for prairie chickens would always exist. Unfortunately, these sanctuaries are also attractive to pheasants, which have become the greatest threat to prairie chickens.

The main problem associated with the coexistence of prairie chickens and pheasants appears to be the result of hen pheasants "parasitizing" or laying eggs in the nests of prairie chickens. Pheasant eggs hatch about two days earlier than those of prairie chickens, sometimes causing the hen to leave the nest before her own chicks have hatched. Even if both eggs are hatched, the problem of harassment of prairie chicks by the larger pheasant chicks can occur. The survival of any species depends on successful reproduction, and the prairie chicken has not been able to effectively coexist with the pheasant.

Insects

Vertebrates constitute a small fraction of the animal species found in terrestrial ecosystems. Most animals are invertebrates, and most invertebrates are insects. An estimated 17,000 species of insects occur in Illinois (Post 1991); several thousand of these must have originally inhabited the vast Illinois prairie. Fortunately, most seem to have survived the near-total destruction of their pre-European settlement habitats. A majority of these animals today inhabit a variety of humanized habitats, such as pastures, hayfields, parks, yards, and fencerows. Some insect species have actually benefited from the alteration of their presettlement plant communities and can often be found in exaggerated numbers in degraded habitats (Ron Panzer, personal communication, Oct. 1996). A smaller but significant number of prairie insect species have not managed to adapt to the modern midwestern landscape. It is not clear what the frequency of remnant-dependency is for prairie insects, but one estimate suggests that probably not more than 25% of species rely specifically on high-quality prairie for habitat (Panzer et al. 1995). These remnant-dependent species are very discriminating in their choice of habitats and are rarely found outside of the context of their native plant communities (Panzer et al. 1995). Isolated as small populations on small, widely scattered prairie remnants, these species must contend with excessive edge effects and the high extinction rates associated with island-dwelling organisms. Having lost more than 99.99% of their presettlement habitats, this group of remnant-requiring animals is clearly vulnerable to the ongoing alteration of the Illinois landscape. Entomologists carry two unique concerns regarding prairie conservation. First, is the commonly used method of evaluating sites by using plants as indicators of habitat quality adequate for identifying sites with high insect diversity (Ron Panzer and Mark Schwartz, unpublished data)? Second, are current habitat management practices having a negative impact on the ability of fire-sensitive insects to survive (Stannard 1984, Panzer 1988)?

Endangered Species

Because 99% of the tallgrass prairies in the Midwest east of the Missouri River have been destroyed, the numbers of individuals of all prairie plants and animals are very small today. For example, the prairie white-fringed orchid (*Platanthera leucophaea*) was once widespread on the blacksoil prairies and has been reported historically from 33 counties in Illinois alone. Today it is known in Illinois from mostly small populations in eight counties, and some of these are under threat by non-native species, unscrupulous collection, and lack of proper management practices (Herkert 1991c, 1994).

Despite the nearly complete habitat loss, we have few instances of global endangerment of species of midwestern prairies. While in 1991 116 prairie species were listed as endangered or threatened within Illinois (Illinois Endangered Species Protection Board 1994), only 7 are sufficiently globally threatened as to appear on the federal list of threatened and endangered species (Table 3.4).

Table 3.4. Federally listed threatened and endangered species of midwestern prairies.

Species	Location								Habitat
	IL	IN	IO	MI	MN	MO	OH	WI	
A. Plants									
Asclepias meadii	X	X	X			X			dry prairies[1]
Boltonia decurrens	X					X			moist places[1]
Dalea foliosa	X								dolomite prairie[1]
Geocarpon minimum						X			sandstone glades[2]
Hymenoxys acaulis v. *glabra*	X						X		dry open places[1]
Lespedeza leptostachya	X		X		X			X	dry prairies[1]
Lesquerella filliformis						X			limestone glades[2]
Platanthera leucophaca	X		X	X			X	X	wet prairie[1]
Platanthera praeclara				X		X	X		wet prairies[2]
Trifolium stolonifera		X				X			dry woods and prairies[2]
B. Insects									
Lycaeides melissa samuelis	X			X	X		X		savannas and open woods[3]
Neonympha mitchellii mitchellii		X		X					prairie fens[3]

[1]Mohlenbrock (1986)

[2]Steyermark (1963)

[3]Michigan Department of Natural Resources (1987)

Examining the federal endangered species lists for Indiana, Ohio, Missouri, Michigan, Minnesota, and Wisconsin only expands the list of globally endangered and threatened species found on prairies to 12 species (Table 3.4). As far as we know, only one plant species that occurred in Illinois prairies is both extirpated and extinct. This plant, *Thismia americana*, was last seen in 1914 (Mohlenbrock 1983). Several animals that occurred on the prairies have been extirpated from the Midwest since European settlement, such as the bison, elk, prairie wolf, mountain lion, sharp-tailed grouse, and black bear (Bowles et al. 1980, Hoffmeister 1989, Mankin and Warner Chapter 7, this volume).

Non-native Species

The tallgrass prairie ecosystem has not only been largely destroyed by the conversion of habitat for agricultural and urban uses, but the remaining fragments are threatened by what has been called *biological pollution* (McKnight 1993). A number of species native to non-prairie ecosystems in other geographical regions, often other continents, have become established in natural communities, including the tallgrass prairie. A recent estimate (Post 1991) indicates that there are 2,068 species of native vascular plants in Illinois. The most recent floristic manual (Mohlenbrock 1986) gives the total number of vascular plants known to be native or naturalized as 2,853. Using these figures, about 27.5% of the vascular plants growing spontaneously in Illinois were introduced from other regions. Slightly different estimates have been obtained using other sources of data (Henry and Scott 1980, Reed 1988). The number of non-native species has increased dramatically with European settlement, from 10.2% in 1846 to something around 30%. The impact of non-native species on prairies is large. In a study of 44 pioneer settler cemeteries on silt-loam soil, Betz and Lamp (1989) found a total of 180 native prairie species, 73 non-native herbaceous species, 22 species of both native and non-native woody plants, and 13 species of cultivated forbs. In a subsequent study of 16 old settler savanna and sand-prairie cemeteries, Betz and Lamp (1992) found 238 native prairie or savanna species, 22 species of woody plants, 64 species of weedy native or non-native herbaceous plants, and 14 species of cultivated forbs. A combined species list for three central Illinois blacksoil prairie pioneer cemetery nature preserves—Loda Cemetery, Prospect Cemetery in Paxton, and Weston Cemetery (K. Robertson, Illinois Natural History Survey, unpublished data), each about 2 ha—shows a total of 186 species, of which 46, or 24.7%, are non-native.

Non-native plant species can be divided into three categories: (1) extremely serious weeds that outcompete native species and threaten to destroy natural plant communities in the prairies; (2) species that occur regularly in prairies but are not overly aggressive and are not likely to further significantly change species composition or frequency in prairies; and (3) species that would probably be eliminated with proper management practices (Robertson and Schwartz 1994).

Different prairies have different disturbance and management practices that affect the occurrence of non-native species. For example, black-soil cemetery prairies are different from other prairie remnants in that they often contain species that were planted as ornamentals.

Given that habitat loss was nearly complete a century ago, one might think that the invasion of non-native species is also a thing of the past. This is not the case. For example, the two most serious non-native species at Loda Cemetery (Iroquois County, Illinois) are daylily (*Hemerocallis fulva*) and cut-leaved teasel (*Dipsacus laciniatus*). Since 1978, these species have increased greatly, and one large colony of daylily has nearly divided the prairie in half, crowding out all native vegetation. Cut-leaved teasel, a recent invader, was first recorded in Missouri in 1980 near Kansas City. Vast populations can now be found along midwestern roadsides where there were few or no populations only 5–10 years ago (Glass 1991, Solecki 1989). The expansion of both cut-leaved and common teasel (*D. sylvestris*) appears to have been assisted by two phenomena. First, the location of population centers along interstate highway rights-of-way suggests that cut-leaved teasel moves with highway construction. Second, horticultural use of common teasel in floral displays at gravesites has resulted in numerous colonizations of cemetery prairies (Swink and Wilhem 1994).

In moist prairies, especially in the Chicago region, common buckthorn (*Rhamnus cathartica*), glossy buckthorn (*R. frangula*), and various bush honeysuckles (*Lonicera maackii, L. morrowii, L. tatarica*) can be serious problems (Heidorn 1991, Swink and Wilhelm 1994). Black locust (*Robinia pseudoacacia*) is a problem in the sand prairies of central Illinois. Another troublesome species in some sand prairies is sour dock (*Rumex acetosella*). Most plant species that invade and encroach upon hill prairies are native woody species, although black locust is invasive on some hill prairies.

The second category of non-native species includes widespread but benign species that occur with regularity in prairies. They appear to be adapted to current climate and management practices, are not overly aggressive, and are not likely to dramatically change species composition in the prairies. There are numerous examples of these in blacksoil prairies, including Queen Anne's lace (*Daucus carota*), wild parsnip (*Pastinaca sativa*) (Kennay and Fell 1992), asparagus (*Asparagus officinalis*), ox-eye daisy (*Chrysanthemum leucanthemum*), and moneywort (*Lysimachia nummularia*). Blackberry lily (*Belamcanda chinensis*) is in this category on hill prairies. Kentucky blue grass (*Poa pratensis*) and Canada blue grass (*P. compressa*) occur widely in many types of prairies. They are cool-season grasses and begin to grow before most of the native species break dormancy. Although these are a serious problem in some prairies, they do not generally seem to be as extremely disruptive as species in the first category, and they appear impossible to eliminate from prairies; mid-spring burns may, however, help reduce the frequency of occurrence.

The third category includes species that will probably be eliminated with

proper management practices. These are species that either persist from cultivation or are opportunistic in disturbances in the prairies. Examples include flowering almond (*Prunus glandulosa*), lily of the valley (*Convallaria majallis*), cultivated iris (*Iris* species), chicory (*Cichorium intybus*), and Adam's needle (*Yucca filamentosa*).

Prairie Management

Some of the most striking habitat changes, such as conversion to agricultural lands, are beyond our immediate ability to correct. Because of these extensive changes, an appropriate question is, What aspect of natural grassland ecosystems should we, or can we, conserve? Table 3.5 summarizes most of the major factors that have resulted in changes in tallgrass prairie. These extensive anthropogenic changes have eliminated the ability of even the largest of our remaining grasslands to exist as fully functioning ecosystems. Two centuries of change in these grassland habitats, without consideration of the many factors that are working in unison to generate these changes, have left our grasslands quite different from what they probably were prior to European settlement. The challenge is how to manage what remains to maintain as much biological integrity as possible.

The single most important stress affecting the remaining midwestern prairies is human exploitation. Consequently, the primary management strategy for the preservation/restoration of the remaining prairie remnants is a no-loss policy combined with a vigorous restoration program. Currently only 6% of the areas listed on the Illinois Natural Areas Inventory are afforded the maximum protection against future changes in land use as dedicated Illinois Nature Preserves (James Heckert, Jean Kearnes, personal communication, Aug. 1995). Seventy-eight percent of Illinois prairie areas are classified as unprotected. The threats of destruction to these unprotected areas are numerous and include building and highway construction, railroad maintenance, grazing, and cemetery mowing. Seventy-three

Table 3.5. Major anthropogenic changes in Illinois grassland ecosystems

Factor	Ramifications
Destruction of habitat	>99.99% loss of grassland habitats.
Drainage	Decreased growing season water availability.
Nitrogenous pollutants	Increased biomass production and invasibility of non-prairie species.
Fragmentation	Increased probability of local extinction and habitat degradation.
Climate change	Shifts in relative abundances, possible local species losses.
Fire suppression	Increased invasion of woody species, shifts in species abundances.
Non-native species	Displacement of native species.
Extirpation of bison	Loss of grazing disturbance resulting in shifts in species abundances.
Domestick livestock	Increased invasion by non-native grasses, loss of biodiversity.

Adapted from Robertson and Schwartz 1994.

percent of these prairie areas are likely to experience major threats within five years, and 9% are in immediate danger (White 1978). Unfortunately, little conservation acquisition effort has been directed toward small sites (Schwartz and van Mantgem, Chapter 16, this volume).

Current Management Practices

The primary management goals for prairie remnants are to increase species productivity and diversity and to reduce the encroachment of aggressive woody and non-native herbaceous vegetation. In general, these goals are accomplished by three management practices: (1) prescribed burning, (2) selective removal of woody or non-native ground cover species, and (3) habitat restoration through planting.

The tallgrass prairie of Illinois is considered a fire-adapted community (Henderson 1982). Historical records indicate that the prairies of Illinois burned frequently (McClain and Elzinga 1994). Thus, it is not surprising that prescribed fire is the most important tool in the development, maintenance, and management of prairies. Fire can be employed for two purposes in prairie management. In new restorations or neglected remnants, fire is used to directly suppress or kill non-prairie species. When fire serves this function, it is important to time the burn such that it coincides with the most vulnerable period in the target species life history (Illinois Nature Preserves Commission 1990). In a healthy system, fire reduces accumulated litter, allowing the prairie plants to gain a competitive edge on their non-native competitors (Schramm 1992). Fires that serve this purpose are usually started in the early spring (although there is a trend toward more fall burning; see the following discussion).

In small preserves the primary management objective is most often to prevent further habitat loss caused by non-native and woody species invasion. The major tool used to accomplish this goal is fire. When used properly, fire is very effective at reducing populations of non-prairie species. However, in cases in which fire is ineffective [purple loosestrife (*Lythrum salicaria*), autumn olive (*Elaeagnus umbellata*), wild parsnip, black locust], managers need to employ methods that selectively remove undesirable vegetation.

Mechanical control techniques such as mowing, girdling, cutting, and hand-pulling unwanted species are a viable alternative to fire. Hand-pulling is recommended for purple loosestrife, autumn olive, Canada thistle (*Cirsium arvense*), and teasel (Illinois Nature Preserves Commission 1990). The effort to control teasel is a good example of the necessity of understanding the biology of a species before undertaking control measures. Although teasel was introduced from Eurasia prior to this century (Werner 1975), it has only recently become a problem weed in Illinois (Glass 1991, Solecki 1989). Because teasel is a biennial species, initial attempts at control involved hand-cutting the flowering stalks and leaving them in the prairie to add to biomass for burning the following spring.

Unfortunately, enough stored energy remains in the cut stalks for seed to set (Solecki 1989, Glass 1991). Control measures now include transporting the cut stalks off site as well as very early spring burns (late January in 1993) when the winter rosettes are exposed and native plants are dormant. The spot application of herbicides has been found to control several woody species on prairie sites (Illinois Nature Preserves Commission 1990). Herbicides used in conjunction with fire or mechanical measures are very effective in controlling undesirable plant species. For example, fall fire facilitates the control of white sweet clover (*Melilotus alba*) by inducing rapid early sprout growth, thereby allowing the application of a herbicide prior to the emergence of the other forbs (Schwegman and McClain 1985, Cole 1991). In contrast, biennial fire regimes encourage sweet clover because the burn promotes germination of seed while the following burn-free year allows plants to mature and set seed. Regardless of the short-term control methods used to regulate non-native plant populations, the long-term goal of prairie management should be toward the restoration of the natural processes (fire, hydrology, etc.) that originally maintained the health of the system.

Suggested Changes in Management Practice

The two most needed changes for prairie management strategies in the Midwest are the frequency and timing of fire. Surprisingly, considering the importance and cost effectiveness of this management tool, fire is not used enough in prairie management (Peter Schramm, Gerald Wilhelm, Steve Packard, personal communications). New prairie restorations or neglected prairie remnants should be burnt yearly for up to a decade. Once a mature healthy system is established, the prairie plants will prevent most of the encroachment of undesirable species. At this stage fire should be applied on a rotation of one to three years. A conservative manager may wish to burn half of the area each year, providing unburned refugia for insects (Schramm 1992).

Changing the timing of the prescribed burn is also being considered in prairie management. In the past, prescribed burns have usually been conducted in the early spring, but most historical accounts of prairie fires indicate that presettlement burning frequently occurred in the fall (McClain and Elzinga 1994). Proponents argue that fall fires burn hotter and will carry over a larger area, while opponents say early spring fires are important for preserving winter wildlife cover and protecting against soil erosion. Both sides, however, agree that fire in either the fall or the spring is better than no fire at all. For more information on fall versus spring burning, see Whisenant and Uresk (1989), and Henderson (1992, 1995).

Prairie Restoration

Habitat restoration has been heralded as a viable technique for the amelioration of habitat loss caused by human activities. The first attempts at habitat reconstruction involved prairies, and the first of these prairie restorations was started at the

University of Wisconsin-Madison Arboretum (Anderson 1972; Anderson and Cottam 1970; Blewett and Cottam 1984; Cottam 1987; Sperry 1983, 1994). The idea originated with Norman Fassett, and Aldo Leopold and John Curtis provided the early leadership. The two prairie restorations at the University of Wisconsin-Madison Arboretum—Curtis and Greene—now total more than 40 ha making them among the largest prairies now occurring in Wisconsin. More than 300 species of native vascular plants have been recorded from the restorations, and they provide excellent habitat for numerous prairie insects, small mammals, and birds (Reich 1971, Selser 1994).

Early stages of work at the University of Wisconsin-Madison Arboretum prairie restoration utilized crews (about 200 people) and equipment from the Civilian Conservation Corps between 1935 and 1941. Because the process of prairie restoration was considered experimental, in 1937 a series of plots was established using different combinations of soil treatment and planting methods. Using seeds, seedling, and sod, single-species block plantings were made of 42 different species up until 1941. Some additional experimental plantings were made during the 1940s, and most large scale plantings of a total of 156 species were made in the 1950s using a variety of techniques, with stratified seed on disced ground under a cover crop giving the best results (Blewett and Cottam 1984). The use of prescribed fires, mostly biennial, has been an integral part of management at the Arboretum prairies (Anderson 1972). Over time, the plant species have segregated themselves according to their optimum moisture regimes. Careful records and maps were kept, and there have been several quantitative surveys and resurveys of the different restoration plots (Anderson and Cottam 1970; Cottam 1987; Cottam and Wilson 1966; Sperry 1983, 1994). As a result, the first prairie restoration has also been the most completely documented prairie restoration.

Several prairie restorations in Illinois have been successful in establishing high biological, or at least botanical, diversity on formerly agricultural or degraded land. A good example is the Schulenberg Prairie at the Morton Arboretum in Lisle (Schulenberg 1970, Johnson and Rosenthal 1992). Initially, volunteers were used extensively to grow plants from seed in a greenhouse, hand-plant the material on the site, and control non-native species. Some direct seeding has been done on additional parts of the site, and there has been considerable species enrichment through transplanting. A complete phenology of prairie species is found at the Schulenberg Prairie, and emphasis has been given to including prairie sedges, which are often overlooked in restorations. Another diverse restoration is the Doris L. Westfall Prairie in Forest Glen Preserve (Campbell and Westfall 1991). Over 120 species of prairie plants native to Vermilion County are found in this site, and most have been introduced through repeated seeding.

The largest prairie restoration project in Illinois, and perhaps the Midwest, is at Fermilab in Batavia (Betz 1986, Mlot 1990). The goal is to convert the entire area enclosed by the nuclear accelerator ring into prairie. The ring is 2 km (1.2 mi) in diameter, 6.4 km (3.9 miles) in circumference, and encloses 314.2 ha (776.3 acres), with an area of 184 ha (455 acres) available for restoration. Additional restorations have been planted outside the ring. As of 1988, over 700 acres of prairie restoration had been planted. Restoration at Fermilab has proceeded by establishing a "prairie matrix" of warm-season grasses together with aggressive prairie forbs to establish a cover of native species that can compete with weedy species. Several years after initial planting, the area is handsown with seed of both forb and grass species that do well after weedy species have been greatly reduced. As this second wave of species becomes established, seedlings are planted of the most conservative prairie species, such as *Gentiana puberulenta*, *Lilium philadelphicum*, and *Habernaria leucophaea*. About 115 native prairie species have been planted in the restoration. Records have been kept of the variety of restoration techniques used at Fermilab. Most tracts that have been under prairie restoration management for over ten years show only a fraction of the floristic diversity of the native prairie. Likewise, the insect diversity on these restorations tends to be low (Panzer et al. 1995).

In the past quarter century, hundreds of prairie restorations have been planted in the Midwest. The vast majority of these contain at most one-fourth to one-half of the plant species that would be found in a natural prairie remnant of comparable size. Several factors are responsible. Because of cost and labor limitations, most prairie restorations are planted with a one-time seeding. Relatively few species (mostly warm-season grasses and rather aggressive forbs) are included in the seeding mixes, a complete phenology of species is not attempted, a number of species included in the mixes rarely succeed from seed, and follow-up species enrichment does not take place. While many of these restorations are aesthetically pleasing, they are not biological replacements for natural prairies.

The success of prairie restorations seems to depend largely upon the techniques used to restore the prairie. While a great many prairie restorations have been planted, few long-term detailed monitoring studies have been undertaken quantifying different techniques, with the notable exceptions of the examples at the beginning of this section. Nevertheless, a number of useful articles and publications exist that contain a wealth of personal experiences with the process of prairie restoration (Campbell and Westfall 1991, Schramm 1992, McClain 1986, Sperry 1994, Shirley 1994). Restorations can be conducted through a process of seeding, planting seedlings, or transferring sod from intact prairie. It appears that transplating sod increases the likelihood of success in establishing soil microorganisms and a fuller complement of vascular flora. The lack of a full diversity of prairie plants, however, should not discourage the use of restoration techniques to increase the total area of prairie in the Midwest. At present, we do not yet know whether these restored sites will eventually become more diverse. Also, over the short term these restoration sites provide habitat for species that are becoming increasingly rare in the state. The application of ecological theory (Burton et al. 1988a,b), such as niche quantification, mechanisms of succession and community stability, and spatial heterogeneity and landscape ecology, may improve the success of prairie restorations.

Conclusions

In the upper Midwest, the tallgrass prairie is gone—left behind are incomplete ecosystem remnants devoid of the full complement of natural ecological processes. These remnants are today under considerable stress from (1) further habitat loss and fragmentation, (2) continued degradation through invasion of woody and non-native herbaceous species of plants, and (3) potentially inappropriate management practices owing to our lack of understanding of the effects of management on a broad array of taxa. Yet, interest in preserving the remaining remnant prairies is strong, as shown by the national efforts of the Nature Conservancy and the Sierra Club and by regional conservation organizations and governmental agencies. Restoration and enhancement projects provide the only real opportunity to increase the total area of tallgrass prairie and to create large-sized sites. The prairie restoration process is labor intensive and applies methodologies based largely on practitioners' experience rather than on science. Most restorations lack the ecological complexity and diversity of remnant patches.

While the situation regarding midwestern prairies is dire from a landscape perspective, there are still fairly complete communities represented in remnants, and very few species have been extirpated from the region or have become extinct. Efforts need to be made to preserve the remnants and restore natural processes to the extent possible. Recently, there has been a shift in land acquisitions for conservation purposes from small but high-quality prairie remnants to large-sized disturbed sites that have recovery potential. While the high-quality remnants are important, larger recovering sites may have greater long-term potential for preserving the tallgrass ecosystem in the Midwest.

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