CHAPTER 13

History and Progress of Ecological Restoration in Tallgrass Prairie

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OBJECTIVES

What were the beginnings of ecological restoration, how has the field of restoration ecology developed, and what role does science have in its application? This chapter explores the development of restoration ecology, centering on early efforts to establish tallgrass prairies and the contrasting approaches taken in the past by practitioners and researchers. How the scientific process can provide guidance to practioners of ecological restoration is addressed. Insights from evolutionary history, plant and animal interactions, and future trends also are discussed.

ECOLOGICAL RESTORATION AND RESTORATION ECOLOGY

During the past century there has been a growing recognition that functioning natural ecosystems, and the important "ecosystem free services" they provide to living organisms, are constantly being diminished (1, 2, 3). This awareness has resulted in increased interest in ecological restoration. Ecological restoration has been defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (4). The broad goal of ecological restoration is a stable ecosystem that is maintained by sustained ecosystem functions, including interactions among living organisms, such as mutualism and predation, hydrological cycles, soil building and maintenance, energy flow, and chemical cycling (5). Motivations for restoration of ecosystems vary. They include compliance to satisfy mitigation required by governmental agencies for environmental damage resulting from public works projects and development on private lands or restoring ecosystem-free service benefits on degraded lands. For volunteers involved in restoration projects, the stimulus can be "spiritual renewal" experienced by persons involved in restoration activities (6). The Society for Ecological Restoration International (SER) was founded in 1988, and now has 2,300 members distributed among the 50 states in the U.S. and in 37 countries. Ecological restoration is carried out by non-profit organizations, such as The Nature Conservancy and the Audubon Society, federal, state, and municipal governments, and commercial organizations (4).

The beginning of ecological restoration may have been initiated without substantial input from science or methods that have a strong science base. Although research through the application of the scientific method has made important contributions to the understanding of ecosystem restoration, the specific role that research plays in restoration of ecosystems has been the focus of considerable discussion. *Restoration Ecology,* the scientific and technical journal published by SER, was initiated in 1993. Of the first 13 issues of the journal, 5 issues contained editorials or comments focusing on the role of science in restoration ecology (7, 8, 9, 10, 11, 12). In most years of publication, there was at least one issue with a comment or editorial considering the role of science in restoration ecology. In an insightful article Hobbs and Norton (13) wrote, "What is clear is that restoration ecology has largely progressed on an ad hoc, site- and situation-specific basis, with little development of general theory or principles that would allow the transfer of methodologies from one situation to another."

Four ingredients necessary for ecological restoration to be successful include: (1) a vision of what the ecosystem being restored should be like when the restoration is finished, (2) an understanding of the ecological processes needed to restore and maintain the ecosystem, (3) knowledge of the specific restoration skills and management practices that are needed, and (4) public support for goals of ecological restoration and confidence in the principles that form the scientific basis for restoration. Research can contribute to all of these components.

THE ROLE OF SCIENCE

The need to define a role for science in restoration ecology apparently is related to the historic development of restoration ecology. Defining a specific time when restoration ecology began would be like looking at the diffuse root system of a perennial grass and declaring a single root apex to be the originating branch of the root. In grasses, the primary root disappears in a relatively short period of time following germination. The root system that develops is composed of numerous adventitious roots, none of which can be declared to be the primary root. The beginning of restoration ecology is no less diffuse.

The restoration of the Curtis Prairie, at the University of Wisconsin-Madison Arboretum, beginning in 1934, is often cited as the first effort to restore a native community (14, 15). While this statement is probably correct, to deem this effort the beginning of restoration ecology would require a narrow view of ecological restoration. This conclusion would ignore practical efforts at rehabilitation of degraded lands such as reforestation or planting of vegetative cover to stabilize eroded lands ravaged during the "dust bowl" of the 1930s. These rehabilitation efforts predated or occurred concomitantly with the beginning of the Curtis Prairie and often involved the use of workers from the Civilian Conservation Corp as did the early years of the restoration of the Curtis Prairie.

Restoration of the Curtis Prairie, an example of a reconstruction (see Chapter 14 of this volume), began without much assistance from science. However, it was Aldo Leopold, a scientist, who proposed that the arboretum be a microcosm of the presettlement landscape of Wisconsin. This proposal served as an impetus for the development of the prairie that historically was a component of the southern Wisconsin landscape. As described later, information derived from scientific methods was not an important factor in the restoration of Curtis Prairie until more than a decade after the project began. The initial efforts at restoration were accomplished by persons who proceeded much as the practitioners of restoration ecology do today. Consequently, the restoration was not a scientific experiment to test a specific hypothesis with treatments and a control. Even though some records were maintained as the planting occurred (16, 17), the information derived was not the sort that would allow conclusions to be made about which planting methods were most successful.

Similarly, the prairie at the Fermi Accelerator Laboratory at Batavia, Illinois, which is arguably among the largest prairie restorations, mostly proceeded as an effort to make a prairie, not as a scientific study (18, 19). The goal was not to test methods of establishing prairies or to necessarily provide good documentation about the restoration process. This is not to say that efforts of this kind have not provided useful information about how restorations should proceed—they have. For example, "The "do's" and don'ts" of prairie restoration" by Schramm (20) is largely information derived from practical experience doing restoration. Schramm tells us what has worked in his experience. What we do not know is the precise conditions under which his prescription worked or what other methods were tested under similar conditions and found to be lacking.

In the first volume of *Restoration Ecology*, the president of the Society for Ecological Restoration made a distinction between restoration ecology and ecological restoration (9). Restoration ecology is a "broad subset of the entire field of ecology, including its theories, tenets, and body of knowledge." Ecological restoration "is the practice of restoring and managing ecosystems." Higgs (21) added specificity to the definition of ecological restoration and described it as "the entire field of restoration, including restoration ecology, politics, economics and cultural dimensions." While there is considerable overlap between restoration ecologists and restoration practitioners, restoration ecology provides the theoretical basis and the principles governing the applied processes of restoration. While restoration can proceed without theory, its progress tends to be limited to specific applications without development of principles.

The features (six cardinal points) that delineate a scientific approach to restoration were outlined by Bradshaw (7). Each point with his explanation is summarized below.

(1) **Awareness of other work**. Being aware of published literature that describes similar work and/or establishes general principles, regardless of where in the world the work was conducted. (2) **Preparedness to carry out proper experiments to test ideas**. Experiments should test what happens when a treatment is applied, but also the result when there is no treatment (i.e., there should be controls).

(3) **Preparedness to monitor fundamental parameters in a restoration scheme**. It is necessary to monitor the change in the structure and function of ecosystems being created. This can be accomplished by identifying and monitoring critical components of the system during restoration.

(4) **Further tests and experiments suggested by these monitoring observations**. Follow-up experiments are often a necessary part of a restoration program to correct deficiencies identified during restoration.

(5) **The restoration of functioning ecosystems in which a variety of species is involved.** The behavior of species is important to understanding the function of ecosystems. Experiments should be conducted that provide information about the behavior of species during restoration.

(6) **Publish results**. Restoration ecologists need to state what was done and describe how the results obtained relate to other sites. Without a body of literature that documents restoration studies, each restoration study must begin anew.

To the scientific community the approach that was being used by some restorationists to establish new paradigms for restoration ecology did not measure up to these standards and was neither basic nor applied research (8, 22, 23). Some work appeared to be a return to subjective appraisal of ecological systems that had characterized the early history of vegetation ecology. This dichotomy to the approach of restoration has been recognized by the Society for Ecological Restoration that now publishes two journals. One journal is mostly focused on publishing ideas and practical applications (*Restoration and Management Notes*—currently titled *Ecological Restoration*) and the other journal (*Restoration Ecology*) publishes scientific studies.

The driving forces for the non-scientific approach taken by some restorationists are probably a mix of unfamiliarity with scientific methodology and a sense of urgency that we do not have the time to wait for results of rigorous scientific studies to provide information about how restoration should be carried out. This also has a practical dimension because there are limited resources for research and restoration on far more lands than can be scientifically investigated. This approach to restoration was supported by Cabin (24) who wrote, "Thus, if one's goal is to accomplish ecological restoration as quickly and efficiently as possible, a trial-and-error/intelligent tinkering-type approach might often be better than using more rigorous, data-intensive scientific methodology." The urgency stems from concern for the rapid degradation of natural landscapes, which we all share.

Scientists interested in restoration ecology must define what kind of research needs to be conducted (25). They must also ensure that their ideas and approaches to delineating concepts and principles are embraced by the practitioners and the public. In some cases, it appeared as if the results of scientific studies were rejected because restorationists were able to generate greater support in the popular press for their ideas than scientists. This point is illustrated by Stevens (26) in his treatments of the differing views held by scientists and some restorationists regarding the origin and nature of savannas. Stevens (26) documents the superb accomplishments of advocates of the non-scientific method of inquiry in engaging the public in the concepts of restoration and motivating them to become involved in restoration activities. The perspective of scientists received fair treatment in Stevens' book. However, science appeared to be overshadowed by the valuable accomplishments of restorationists in areas other than science (e.g., developing volunteer networks, stimulating public interest and support, and generating creative ideas about restoration). These accomplishments appeared to increase the credibility of restorationists in the savanna debate. At that time, the non-scientific approach to restoration seemed to be gaining some support even from within the scientific community (27).

INTEGRATING SCIENCE WITH PRACTICE

Practitioners and restoration ecologists have made, and will continue to make, valuable contributions to ecological restoration. Nevertheless, it is important to understand how the approaches to solving problems taken by the two groups differ to make the most effective use of the information they generate. Greater effort should be made to foster dialogues between research scientists and restorationists (28). Criticism that Risser (29) made of ecologists and their interactions with resource managers might in some instances also apply to restoration ecologists and their relationship to restorationists: "It is patently unfair to publish papers in conventional scientific format and then criticize the less sophisticated consumer for not finding and/or not using the information correctly. As ecologists, we must change our approach from that of criticism to one of assistance." Risser further proposed that research scientists include a summary of their work that clarifies how it has practical applications for resource managers. The journal of *Restoration Ecology* currently requires that authors summarize the practical relevance of their studies at the end of each article under the heading, "Implications for Practice." On the other hand, restorationists should increase their familiarity with the growing body of literature which has direct application to ecological restoration, but is published in sources they may not usually search. While ecological restoration can be done as an "ecological garden" (24, 30), it benefits from information and ideas generated from research carried out by restoration ecologists.

The development of adaptive management potentially provides a bridge between the approach used by restoration ecologists and restoration practitioners. In adaptive management, restorations are deliberately designed as experiments. It begins with an assessment of the objectives of the restoration, the resources needed and methods available to achieve these objectives, and performance measures that could be used to monitor progress in achieving the objectives. From the assessment, a restoration plan, an experimental design with testable hypotheses and predictions, and a monitoring plan are developed. The restoration plan is implemented and progress towards achieving the restoration goals is monitored. Evaluations are made of progress by analyzing monitoring data to determine if the restoration goals are achieved, if hypotheses are supported or rejected, and whether predictions based on hypotheses were accurate. If goals are not met, then restoration practices, policies, and plans are adjusted based on the information obtained. Thus, adaptive management allows restorations to proceed and be adjusted as needed, based on the results of experimental data (31).

RESTORATION ECOLOGY AND RESTORATION OF PRAIRIES

In this section, the development of restoration methodology for the tallgrass prairie ecosystem is examined. This examination illustrates some of the ways that research has contributed to understanding this restoration process and provides model endpoints that serve as the basis for determining the success of restoration efforts.

THE FIRST PRAIRIE RESTORATION

The first major effort at prairie restoration began at the University of Wisconsin-Madison Arboretum in 1934 with the restoration of the 25-ha Curtis Prairie (14, 16). Prior to European settlement, most of the area occupied by the arboretum was oak savanna. The area now occupied by the Curtis Prairie was settled by Europeans in 1837. It was regularly plowed and planted to field crops until the early 1920s (32). The abandoned field was then used as a horse pasture from 1927 to 1932, during which time the site became dominated by Kentucky and Canadian bluegrasses and was devoid of prairie plants.

Under the supervision of Theodore Sperry, Civilian Conservation Corp workers collected sods from local prairie remnants. The sods supposedly contained a single species and were planted in monospecific blocks (17). The sods, however, contained a mixture of prairie species in addition to the target species, so the monotypic nature of the plots was never perfect (14). The sods were planted among the bluegrass, generally with little or no pretreatment of the site. The initial planting program ended in 1940 and no additional plantings were made until 1950 (14 ,16, 17, 32, 33).

In the 1940s and 1950s, several studies were conducted that generated information needed for the restoration of native prairies. Intensive examination of the composition of native remnant Wisconsin prairies (34, 35, 36) provided data about what the restored community should resemble. Additional research included studies of seed germination of prairie plants, pretreatment of the planting sites, and the use of cover crops for prairie restoration (37, 38, 39, 40, 41).

One of the most important discoveries of the early studies of prairie restoration at Wisconsin Arboretum was the successful use of fire as a management tool (42). Fire, appropriately used, was found to be effective in retarding the growth of cool season (C3 photosynthetic pathway) exotic weeds, such as Kentucky Bluegrass, while enhancing the growth of the warm season (C4 photosynthetic pathway) prairie plants and their flowering and seed set (32, 39, 40, 43, 44, 45). Since 1950, the arboretum prairies generally have been burned biennially (Fig. 1, Fig. 2).

Figure 1. An early precribed burn conducted on the Curtis Prairie on the University of Wisconsin campus near Madison in 1950.

Figure 2. A prescribed fire in the Curtis Prairie in 1970. Photo by Roger C. Anderson.

Monitoring the progress of the prairie restoration at five-year intervals began in 1951 using meter-square quadrats to obtain presence-absence plant data. The quadrats are located on a 50-ft x 50-ft grid system that is distributed over the prairie. By 1961, portions of the Curtis Prairie were similar to native prairie stands (Fig. 3) in terms of the number of indicator species and summed frequencies of the prairie species (14, 46).

The 20-ha Greene Prairie, another reconstructed prairie at the Madison Arboretum, is considered to be one of the best examples of restored prairie anywhere. It is comparable in diversity to good quality native remnant prairies of equivalent size and occurring on similar soils (14, 45, 47). Plans for the establishment of the prairie were formulated in 1942 by Henry Greene, for whom the prairie is named. Planting of the site was carried out almost entirely by him. Greene considered the original vegetation of the site to be of the sand prairie-oak opening type (48). However, the area supports prairie vegetation ranging from dry to wet prairie (49). Before the site was acquired by the arboretum in 1941, sporadic attempts were made to farm the entire area now occupied by the prairie. Nevertheless, farming did not completely eliminate prairie species and one corner of the site was relatively unaltered (49). Intensive efforts at prairie restoration began in 1945 and continued through 1952 (48, 50). Prairie species were introduced on the site by planting seed or seedlings grown in the greenhouse, transplantation of small blocks of prairie sod, or by the introduction of mature prairie plants (37).

Henry Greene was an excellent field botanist, although his training was in plant pathology. He apparently became extremely proficient at identifying vascular plants, which served as hosts for the fungi he studied (personal communications, Grant Cottam). His knowledge of the habitat requirements of prairie species was exceptional and he collaborated with the well-known plant ecologist John Curtis on several studies (34, 37, 51). When Greene planted species on the site, they were planted in habitats that he thought were best suited to their ecological requirements. It is of interest that Henry Greene recommended that forbs be planted and established before grasses were planted, a recommendation that has been followed for more recent restorations (49). Like the Curtis Prairie, the Greene Prairie has been systematically sampled at five-year intervals using quadrats positioned at standard locations (14, 49).

Within the Greene Prairie changes in quadrat frequency for prairie indicator species, between 1952 and 1966, revealed that species' abundances and distributions

Figure 3. Curtis Prairie during July of 1971. Photo by Roger C. Anderson.

shifted within sectors of the prairie based upon the availability of soil moisture. Drier sites occurred on upper slope areas and had sandy soils and lower topographic areas had soils with a finer silty texture and were wetter. Species changes were toward the soil and drainage patterns most similar to the native prairies in which they naturally occurred (49). These results indicated that, over time, species occurring on a restoration site may segregate so they occupy sites most suitable for their optimum growth. During the same period of time, weedy exotics decreased in abundance, while the abundance of prairie species increased. Over the decades, the Curtis and Greene restored prairies increased their similarity to native prairies, yet remained somewhat imperfect replacements as they contain few of the grassland animals and non-native plant species (e.g. Kentucky Bluegrass, sweet clovers, Poison Parsnip, and others) are abundant in portions of the prairie.

As a footnote to the efforts and success of restoring the Greene Prairie, the *Friends of the Arboretum Newsletter* (January 1996) carried an article describing urban development adjacent to the prairie that produced excessive storm water runoff and seriously damaged portions of the prairie. Efforts are being made to mitigate these effects, as well as those anticipated to occur, as a result of future urban development projected to occur immediately south of the prairie (52). These problems point to the need for constant vigilance to insure the integrity of natural or restored ecosystems.

INTEREST IN PRAIRIE RESTORATION GROWS

From the late 1960s and into the 1970s, there was an expansion of a movement to restore native prairies and plant native grasses and legumes for roadside cover, forage for domestic livestock, and as a landscape planting (53, 54, 55, 56, 57). The methods used by these restorationists varied from transplanting prairie seedlings grown in greenhouses to drilling seeds of prairie species into sites prepared by tilling and disking to control competing weeds. The methodology outlined by Schramm (56) became the standard guide for many restoration efforts and was essentially the procedure recommended for the next two decades by other references that were often used by groups and individuals interested in restoring prairie (e.g., 58, 59).

The recommended restoration procedure involved intensive site preparation to remove any existing vegetation. For example, on sites with well-developed sod, fall plowing, followed by additional cultivation in the spring, was recommended to control weedy exotics before plantings were made. Locally collected or commercially purchased seeds were provided with cold-moist stratification and hand broadcast or drilled on the site. Specially designed drills were developed to handle the native prairie seeds with their numerous bristly structures (eg., trichomes and awns). Planting usually occurred in middle to late-spring and occasionally in the early part of the summer, after the extensive cultivation to control weedy plants. Late planting risked exposing seeds to insufficient moisture to allow seeds to germinate and successfully establish seedlings. Prescribed burning in the spring was recommended when the site had sufficient fuel to carry a fire, usually in the second spring following planting. Relatively high density plantings of grass seeds were initially recommended (one to three dozen grass seeds per square foot) to ensure rapid development of a restored prairie on the site (56). However, many of these techniques have been modified or are no longer used by restorationists (60).

CHANGING VIEWS ON PRAIRIE RESTORATION

From the beginning of prairie restoration in the 1930s and continuing through the 1970s, with some exceptions, the focus had been on establishing a plant community with relatively little thought given to other groups of organisms. The net result was that restored prairies were more like prairie gardens than functioning ecosystems. The high seeding rates for grasses that were used, the difficulties associated with obtaining sufficient quantities of forb seed, and the planting of forb seeds at inappropriate depth by seed drills set for planting grasses, resulted in nearly monotypic stands of prairie grasses with low abundances of forbs (61, 62). Nevertheless, some very high-quality restored prairies were established during this era such as the partially hand planted Schulenburg Prairie at the Morton Arboretum in northeastern Illinois (55).

By the 1980s, the focus of research and restoration efforts were broadening to include considerations of other groups of organisms, such as invertebrates (64, 65, 66), birds (67, 68), small mammals (69, 70, 71), large mammal herbivores (72, 73), burrowing mammals (74, 75), fungi (76), and mycorrhizal fungi (77, 78, 79). Initially, many of these groups of organisms were studied independently without considering how they interacted to affect functional aspects of ecosystems or the evolutionary processes that resulted in these interactions. It has been only in the past two decades that a more comprehensive view of prairie restoration began to emerge. While the interaction between science and ecological restoration has been weak in some areas (24), the melding of research and restoration of prairies has been strong and the potential for science to contribute information useful to prairie restoration is high.

MODIFYING OUR VIEWS OF PRAIRIE RESTORATION

USE OF FIRE

The increased amount of information about prairies (80) resulted in modification of some standard management practices. For example, even though fire is the most widely used tool in prairie restoration and management, deciding on an appropriate grassland management fire regime to accommodate the wide array of responses prairie species have to fire is complicated as illustrated by the response of invertebrate species. Invertebrate response to burning is dependent upon a number of factors, such as how the microclimate and structure of the vegetation is changed after fire, the location of invertebrates when the fire occurs, and how well the invertebrates adapt to the changed environment post fire (63, 64, 81, 82, 83). For example, during a fire that had surface temperatures of 200^{o} C, species of spiders that were active on the soil surface were eliminated, whereas species in subsurface burrows, under rocks, or in the bases of caespitose (clumped) grasses survived the burn (63). Butterflies (84, 85), and leafhoppers decrease in abundance after fire (64), but mixed responses of species to fire were reported for mites (81), collembolans (64), and grasshoppers (86). As the frequency of fire decreased, some grasshoppers feeding on forbs increased in frequency; however, other species of grasshoppers increased after fire and/or showed rapid recovery post burning (83, 86).

Thus, a single management prescription that will be acceptable for all invertebrates is not likely to be feasible. Some entomologists think that current burning practices harm prairie insects, and if continued, might result in a substantial number of species becoming extirpated (87, 88). To conserve butterflies, Swengel and Swengel (85) recommended that permanent non-fire refugia be established and managed with other methods, such as brush cutting and mowing, if necessary. In contrast, Panzer and Schwartz (89) concluded that conserving insect biodiversity is compatible with the current fire rotational plan used in Illinois (burn about every two to three years). In the extensive historic grasslands, fires left some areas unburned each year and these areas would have provided refugia for fire sensitive insects. Burning fragmented remnant prairies or restorations under current conditions often results in all or nearly all of the intended burn unit being treated with fire. To provide unburned refugia for insects sensitive to fire, it is recommended that only 30% to 50% of a site be burned, with the assumption that fire sensitive species can reinvade the burned area during the growing season following the burn (65, 89, 90, 91). Leaving areas missed by the fire unburned, burning in the early morning to reduce intensely hot fires, and conducting spring burns to retain grass clumps for insects to use as wintering sites are additional recommendations to favor sensitive insects (65).

INCOPORATING EVOLUTIONARY HISTORY

New approaches to restoration should consider the evolutionary relationships among organisms that resulted in interactions that are essential to a functionally stable ecosystem. The coevolution of large herbivores and grassland species may provide the best example of how an evolutionary view of organism interactions can be applied to restoration. Grasses are among the dominant species in prairies and are adapted to drought, fire, and grazing. Having below-ground perennating organs may be a pre-adaptation to all three of these factors. However, there are other features that indicate a co-evolutionary relationship between grasses and grazers. These features include presence of silica in epidermal cells in grasses and hypsodonty (high-crowned cheek teeth) in grazers, both of which appeared in the Eocene, and compensatory aboveground growth following grazing (72, 73, 92). The expansion of grasslands and savannas worldwide post-Miocene was associated with the radiation of large mammals adapted to grazing and grasslands and savanna habitats (72, 73, 92).

In North America, the primary large mammal grazer since the end of the Pleistocene has been the bison. The bison is considered by some to be a keystone species (93). However, it has been only in the last two decades that grasslands large enough to permit bison to function as they did historically became available to study (73). Burning and grazing accelerates the rate of mineralization of inorganic nutrients, such as nitrogen, but without volatilization, which contributes to nitrogen loss from prairies (94). For example, grazers like bison are effective in changing some recalcitrant forms of organic nitrogen to urea that is easily converted to ammonia, which plants can readily use. The increased availability of inorganic nutrients can enhance grassland productivity (93).

Bison grazing can increase plant diversity and spatial heterogeneity of grasslands (93, 95), which has been shown to increase the diversity of grassland birds (67, 68, 96). While grasses are the dominant plant species of prairies, it is the forbs that contribute most of the species richness (97). About 90%–95% of the diet of bison is grass and they consume few forbs. Bison graze in patches, which they repeatedly graze and abandon when grass forage is reduced. Grazed patches that regrow during the growing season are preferred by bison over ungrazed areas, because grazed patches contain higher-quality forage. Repeat grazing of patches reduces the competitiveness and dominance of grasses, thereby encouraging forbs and increasing diversity (73, 93). Grazing affects fire patterns by producing a patchwork of vegetation varying from heavily grazed areas with low fuel loading to sparsely grazed areas with heavy fuel loading. The varied fuel pattern results in a mosaic of intensely and lightly burned areas that favors high diversity of small mammals (71) and insects (89, 98).

Grazing as a grassland restoration tool has not been extensively applied, especially in the eastern portions of the tallgrass prairie. However, grazing returns a historical function to grasslands that has the potential to increase grassland diversity. Burning and grazing are combined in a management practice termed "patch-burn grazing," which may enhance grassland diversity (99). In this management practice, grazing animals (cattle or bison) graze freely across the prescription area that has recently burned and unburned patches. Cattle, as well as bison, prefer to graze on burned areas more than in unburned areas in the first year after the fire. The intense grazing in the burned area creates openings and reduces the competitiveness of dominant C4 grasses (e.g. Big Bluestem and Indian Grass) that are preferred forage over forbs for both bison and cattle and encourages the growth of the unpalatable forbs (100). On restored prairies with high dominance of C4 grasses and low forb diversity, the heavily grazed and burned areas could be sown with forb seeds to enhance species richness (99, 100). In the following year, the pattern of burned and unburned patches is reversed allowing the seeded forbs to become established. However, grazing is not an option on all prairies because of size limitations and other factors.

Leach et al. (101) suggested that historically in the eastern portion of the tallgrass prairie bison were not as abundant as they were on the mid- and shortgrass prairies. As a consequence they suggest a strong interaction between grazers and eastern tallgrass prairies did not evolve and there are plant species sensitive to grazing, although this issue remains unresolved (102, 103). Nevertheless, depending upon restoration goals, grazing may be a useful restoration tool even if there is uncertainty about whether it was historically important in a region. For example, the Midewin National Tallgrass Prairie in northeastern Illinois has the largest nesting population of Upland Sand Pipers in Illinois. During the time of nesting the bird requires short grass and a relatively unobstructed horizon (67). The nesting habitat for the grassland bird is maintained by cattle grazing on cool season domestic grasses. An important restoration question that needs to be determined is whether native grazers or their surrogates can produce similar habitat structure utilizing native prairie.

Elk and White-tailed Deer historically may have been important in retarding woody plant invasion into grasslands and these species or their surrogates (goats and cattle) may be useful to control woody vegetation invasion into prairies. In central Illinois, the ParkLands Foundation uses cattle grazing to control invasion of woody exotic shrubs [e.g. Autumn Olive (*Elaeagnus umbellata*), Amur Honeysuckle (*Lonicera mackii*), and Multiflora Rose (*Rosa multiflora*)] into cool season domestic grass and native prairie grass plantings that are maintained for grasslands birds. Similarly, cattle grazing may be useful to retard invasion of woody plants into loess hill prairies in Illinois. Between 1940 and the present, more than 50% of the area of hill prairies was lost, largely due to the invasion of woody species, which can reduce flammable fuels and suppress prairie plants by shading (Chapter 4). Even hill prairies that received periodic burning experienced a decline in area due to woody invaders. In the past century, most hill prairies were subjected to grazing, and heavy grazing by cattle can degrade them. However, control of woody invaders may be achieved by moderate to light grazing (104). On similar vegetation in Wisconsin, Curtis (36) stated that "... some dry prairies on thin soil hillsides are known which have been grazed continuously for over a century but they are still dominated by the two grasses mentioned above (Side-oats Grama Grass and Little Bluestem) and still contain a number of their typical forbs…" Thus, grazing may have a role to play in restoration and management of prairies in areas where our limited evidence of historic patterns suggests grazing may not have been an essential part of the prairie ecosystem.

THE FUTURE OF PRAIRIE RESTORATION

Public interest in prairie restoration has grown during the past three decades, and there has been a union of interest in prairie restoration among scientists, federal and state personnel involved in management and restoration of prairies, private organizations and foundations, and the general public. This is illustrated by the expanded attendance and diversity of expertise represented at the North American Prairie Conferences, which have been held at two-year intervals since 1968. The first conference was held at Knox College (Galesburg, Illinois). The conference was attended by 120 people, including scientists, government personnel, naturalists, and lay people. Subsequent conferences have attracted a large portion of the attendees from the general public, many of whom often have gained experience in prairie restoration through volunteer programs. The size of the conferences has grown to as many as 500–600 attendees. There has also been the development of commercial nurseries and landscaping companies that specialize in the planting of prairies and/or selling of prairie plants or seeds. In Illinois, private grass roots organizations, such as the Grand Prairie Friends, Save the Prairie Society, and the ParkLands Foundation, work to save remnant prairies and are involved in prairie restoration. Nationally, private organizations including The Nature Conservancy, the Audubon Society, and federal agencies such as the Natural Resource Conservation Service promote prairie restoration and protection of remnant prairies. Home owners and private corporations are using native prairie plants for landscaping and in several states prairie grasses and forbs are planted along roadways. Prairie plants, especially grasses, are extensively planted in the Conservation Reserve Program to protect and rebuild erodable soils. This broad base of support for saving remnant prairies and prairie restoration has laid the ground work for continued interest in understanding the ecology of prairies and prairie restoration.

SUMMARY

As a formalized body of knowledge, ecological restoration is a recent phenomenon, with scientific journals first addressing the topic in 1981. Ecological restoration has borrowed from the principles of ecology, used practical information generated by practitioners and depends upon them for meaningful application of principles developed by restoration ecologists. Several authors (105, 106, 107, 108) proposed that restoration ecology can serve as a heuristic experience and a test of ecological theories, because it provides researchers with the opportunity to test their ideas on the nature and functioning of ecosystems. They further suggested that in the process of putting an ecosystem back together we learn about the structure and function of that system. Given the extensive alteration of ecosystems that is likely to occur worldwide in the next several decades, the importance of restoration ecology and ecological restoration should only increase because of the potential for restoration to generate stable self-sustaining ecosystems that will continue to provide ecosystem-free services. Cottam (14) stated, “In prairie restoration there is no substitute for knowledge...” and it is apparent that this statement applies to all restorations and should guide ecological restoration as we approach the challenges presented by alteration of the earth’s environment on a global scale.

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