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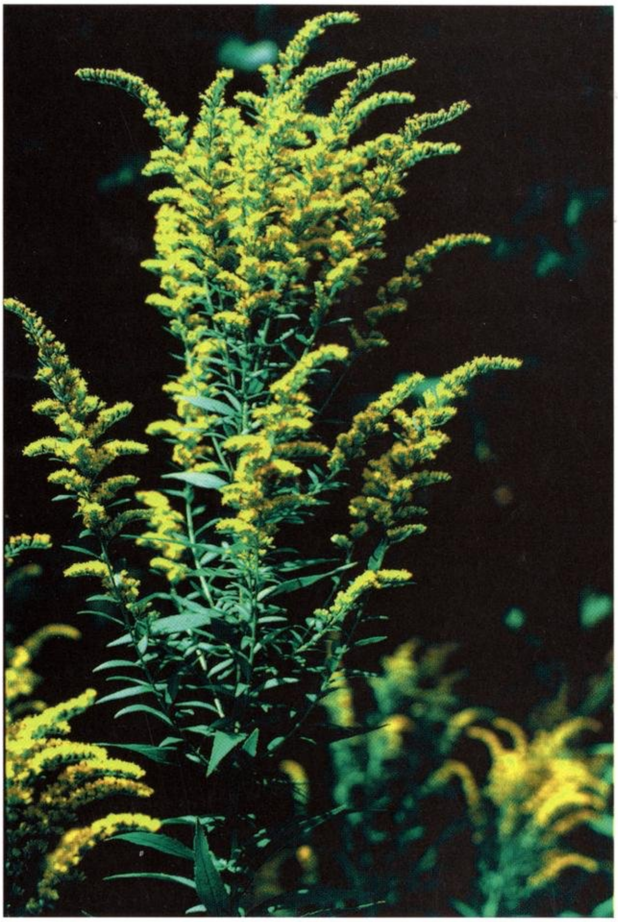
The Central Nebraska Loess Hills Prairie

PROCEEDINGS OF THE SIXTEENTH NORTH AMERICAN PRAIRIE CONFERENCE

Edited by Joseph T. Springer



Canada Goldenrod, by Steven Rothenberger, UNK Biology Department

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Proceedings of the Sixteenth North American Prairie Conference

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PRAIRIEFY THE CITIES: INSPIRATIONS FROM NEBRASKA

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Abstract: The expansion of cities is, perhaps, the most significant physical planning phenomenon of the twentieth century. All landscapes have suffered from this irresistible conquest, and it is assumed that this Tyranny of Urbanization shall continue indefinitely, as populations increase exponentially. The prairies suffer most from urbanization in that less effort is required to subdue the topography, to fell the forests, to drain the marshes and to sacrifice the fields, so profitable for the urban invasion of such subtle landscapes. It is time to reverse this seemingly inevitable process by devising the practical ruralization of the cities by applying the ecological discipline of the prairie, and restore something of the natural vitality of the biodiversity and that special aesthetic of the prairie scene. Such practical policy, such planning prudence, such design innovation, can benefit simultaneously the economics of city management, wildlife adaptation, the dynamics of water husbandry, and the cultural standing of the citizen. The central influence of Nebraska and the initiative of its inhabitants has already demonstrated the practicability of the concept of urban ruralization. The arboricultural leadership of entrepreneur J. Stirling Morton; the prairie enthusiasms of planner Emiel J. Christensen, and the design abilities of Lawrence A. Enersen combine to demonstrate that Nebraska is already the inspiration for a vigorous design concept based upon synecology, synecotectural planning, and synecopolitan planning. The urbanization of eastern Colorado is evidence enough for alarm over the loss of the subtle aesthetic character, economic response and natural resource of prairies everywhere. If this landscape is so appealing as human habitation, it must have a strong message for the urban inhabitant. It is not time to "Prairiefy the Cities" rather than to citify the prairies.

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Key words: biodiversity, Emiel J. Christensen, J. Stirling Morton, Lawrence A. Enersen, prairie esteem, synecology, synecopolitan planning, synecotectural planning, urban ruralization.

An ecological imperative has emerged requiring immediate planning attention. The heading for my recommendations may sound flippant but the subject is serious, the purposes urgent and the prospects positive.

"Prairiefy the Cities" expresses, briefly, a practical alternative to the continuing urbanization of the prairies, an all-too familiar process that is depriving the nation of a very special series of landscapes and economic assets. This pernicious practice reduces further the vital process of photosynthesis.

Every Prairie State is subject to the environic malady of increasing suburbanization by the spreading array of housing and by urbanization that follows in the form of shopping centers and all the structural paraphernalia of sophisticated social hysteria sustained by service strips, the inevitable consequences of roads and highways of haste.

The prairie landscapes may now be regarded as tourist investments, as a psychological tonic, and as a social escape. The human desire for spaciousness will bring, inevitably, a deep desire for the "open" view denied to the desperate citizen. Population pressure now represents a psychological "power," more forceful than at any time in human history, and the prairie is an inevitable battlefield. Distance represents spiritual vitality that has become a commercial commodity.

As evidence of this desperate factor of human self-compression, I refer to the recently produced "Maps of Silence" published by Her Majesty's Stationary Office, showing those areas of the United Kingdom where silence may be found, where freedom from noise, aircraft, highway, industrial and habitational sounds may be enjoyed. Silence is now hard to find, and may be instantly shattered by the arrival of someone with a radio used as a defense against the sense of isolation, by agricultural machinery and, especially, that infernal lawn-mower (the smallest machine with the highest decibel rating, yet deliberately devised).

Of course, silence is never absolute, as I heard on 4 October 1957. I was attending the initial calibration of the world's first radio telescope, attuned to listen to the Heavens, only to hear the "peep-peep" of

Sputnik. The mighty Jodrell Bank Radio Telescope was the only means of hearing the success of this startling Soviet innovation which heralded the invasion of space.

The "Sounds of Silence" was the eloquent title of a stunning slide-show given in celebration of the plains of Texas in 1966, in the presence of Ladybird Johnson (who has done so much to enhance the quality of the American landscape by making environic conditions a political issue, for the first time, with her White House Conference of Natural Beauty, 33 years ago). Governor Frank B. Morrison addressed this same assembly on "The Dominion of Man" at the Texas Conference on an Environmental Crisis, University of Texas, Austin, 1966.

The search for silence is now serious business. The visual counterpart of silence is the spiritual refreshment of uninterrupted views which endow these varied prairies with exceptional scenic subtlety. This is illustrated dramatically by the Nebraska prairie painter, Anne Burkholder, and was defended valiantly by Governor Frank Morrison at the time of construction of the first Interstate Highway. As an attorney, he was determined that these unique horizons should not be interrupted by incidental billboards of Babel, the vanguard of persistent urbanization. This is now the only super-highway adorned with majestic sculptures (Bicentennial Monuments) at rest-stops throughout its 420 miles across the state, to which is to be added the Millennium Bridge. (A bridge is for viewing as well as for crossing.)

Even the layout of the world's most exclusive recreation pitch, the Sandhills Golf Club at Mullen, exposes the prairie topography, in model form, in contrasting the ridges of rough grasses and undulating lawns manicured like Italian velvet. These intermittent, inter-related lawns, undulating like an oceanic swell, may be the ultimate argument in prairie popularity. (However, I would challenge the ecological effects, the irrigation consequences and the social implications of such an investment.) This has imposed, however, an unprecedented commercial value upon remoteness, aesthetic emotion, wilderness, and the prospect of silence. It is the antithesis of urbanization to which the prairies are now so vulnerable.

It is in this context of social turmoil and of "increasing scarcity," that I plead for the encouragement of the prairie aesthetic, and urge the prairiefication of cities.

No place is more appropriate then Nebraska for such an appeal to "Prairiefy the Cities." Here there is a special and eloquent literary tradition, from Willa Cather onwards, in praise of the prairies and the disciplines it imposes upon its inhabitants .

The symbolic significance of the horizon has yet to be defined in psychological, social and economic terms. That is because it represents the opposite extreme in landscape experience to the enclosing mountains, enwrapping forests, and especially the confining fabric of the cities. Only the oceans can provide that emphatic horizontal emphasis that confirms the global form of the earth.

It is time, indeed, that some practical policy of retaliation be developed in defense of the prairies. This is a matter of innovative design, whereby the natural prairie vitality becomes a commercial force. The prairies are vital in the essential continuity of agrostology.

I am speaking, of course, as a planner, an architect, and as an environologist concerned with the practice of the ultimate human obligation: environic quality. This ensures human benefit within the context of environmental harmony and productive continuity.

Design is the insurance for economic return, even as aesthetic appreciation is the discipline of practical design.

I appeal for your critical comment on my plea that prairie grasses should be identified, popularized and cultivated for their special biodiversity, so evident for the natural vitality of the prairies, for use on urban roofs.

Synecology

I appeal for a prospect, program, and policy of agrostological roof planning and planting as an essential feature of all prairie lands habitations. These should be consistent with regional characteristics, from northern Alberta of Canada, to the Chihuahua highlands of Mexico. They should appreciate the infinite variations of landscape from the Pecos Valley to the Platte River Valley, to the Red River of Manitoba. They should include, of course, those regions of Wisconsin and Illinois which so inspired Frank Lloyd Wright and his characteristic structures identified as "The Prairie Style."

This design "style" should now be expanded and cultivated as prairie "esteem" in appreciation of the indigenous vegetation available for the benefit of cities. More than a "style" is now required, for style, like fashion, represents a temporary mood. I am concerned with "esteem," as a continuous rating of high regard based on logical validity.

"Prairie esteem" should be perpetual in terms not only of a particular architectural convention, but as a design inspiration in terms of synecology. Here, vegetation is used as an integral part of any structural facility for the provision of thermodynamic benefit, maintenance economy, aesthetic value, wildlife habitat and spiritual uplift.

The European settlers of the Nebraska prairies found that grassroots, in the form of sod, provided effective shelter. It is time that these structures (such as remain) were re-examined for their thermodynamic characteristics, security and longevity, vanquished only by the alleged advantages of air-conditioning, refrigeration and other costly devices.

Synecotecture and Synecopolitan Planning

The wildlife benefits consequent upon the clothing of buildings with indigenous vegetation now justifies full agri-biological review of the use of plant life upon walls and roofs to determine chlorophyllic yields, insect vitality and bird-response. This practice represents the opposite extreme to that of monoculture commitment, even as a biodiversified hedge is to a cultivated field.

In brief, I am proposing that the prairies can provide the means of energetic retaliation to urbanization which has become such a threat to the grassland scene.

It must soon be realized that the cost of human development includes the unestimated reduction in the photosynthetic processes provided by the vegetation that has been sacrificed. Vegetation, in its infinite variety, should now be considered as a means of clothing structures. In that way, photosynthetic vitality would not be further reduced as a result of urban expansion. Vegetation becomes, therefore, the essential instrument of urban vitality, health and practical economy: a system of true insurance.

The long-known process by which plants form carbohydrates from CO_2, inorganic salts and water by the effects of sunlight acting upon chlorophyll is essential to all life. But I have seen no estimates establishing the extent to which building construction has reduced this essential life-sustaining productivity.

The ever-increasing reduction in photosynthetic productivity is all too obvious in most cities. Its redemption is possible by exploring the science of synecology and developing the practice of synecotecture and synecopolitan planning.

Roof Plantings

Nebraska, this central state within the nation, is the most logical location in which to test the benefits of vegetation as an integral part of almost any building.

How far can the effects of drought, fire, floods, forest depletions and the ever expanding areas of hard surfaces spread before the declining photosynthetic production becomes critical to biological continuity? Have any such estimates been made?

A national campaign is long over-due to inform the public of the values of vegetation beyond the provision of food, the essential sustenance of wildlife, and the aesthetics stimulation of spirit.

The prairies, I plead, provide the most obvious ecological instrument in the fulfillment of ecological balance, in general, and urban synecology in particular.

THREE ECO-HEROES

Before proceeding with the details of my synecological concern, I must pay tribute to 3 Nebraskans whose influence upon the scene is already immense. These 3 eco-heroes symbolize the changes of scene over the past century, with the emphasis upon trees, the appreciation of prairie horizons and their peoples, and with the demonstration of rural/urban interface.

J. Sterling Morton (1832-1902)

J. Sterling Morton, a former U. S. Secretary of Agriculture, was founder of the National Arbor Day Foundation in 1872. His very personal memorials are to be seen in the arboricultural glories of his home and demesne at Nebraska City, Nebraska, and also at the Morton Arboretum, in Lyle, Illinois.

While trees are not synonymous with the prairie scene, they are the mark of European invasion from the tree-covered east. Shade, thermal control, fuel, and eventually building material, were essential factors in the life for the invaders, and trees provided each requirement. As settlements were created and towns laid-out to a plan, the proportion of resources, capital and labor devoted to the importation of street trees compared with building materials justifies review.

Such expenditures on trees would be considered now as grossly disproportional. These same trees have since been cut-down because they conceal advertisements, they hinder the parking of vehicles (instead of shading horses), while their leaves and branches are considered "hazardous." The sanctity of the tree is now ignored, and the fabric is regarded as a nuisance.

The selection of species that would withstand the climatic severities and give character to the landscape was of prime importance. Eventually, the value of trees was established: shelter-belts prevented further dust-bowling, provided shade for livestock, replenished soil fertility, and increased atmospheric and soil humidity. But now, even these trees are being destroyed in favor of fields sustained by regimens of irrigation.

The introduction of trees on the prairies may seem an irrelevant issue at a conference devoted to the appreciation of native grasses. But this arboricultural effort was an essential factor for the initial urbanization of the prairies. And it is the basis of my plea for the grassification of the cities as an equally essential act of urban ecological revivification: a retaliation for trees on the prairies by providing grasses on the roofs of cities.

Is it not time for an echo of Secretary of Agriculture Morton to establish, here in Nebraska, a "National Agrostis Day Foundation?" It would be devoted to the promotion of agrosticulture: education in the appreciation of grasses in their fascinating varieties, and in the practical uses of grasses in environic economy and aesthetic quality. It would be similar to what Presidentessa Ladybird Johnson has done for indigenous wildflowers in establishing the National Wildflower Studies Center.

Once more the construction of domestic buildings of baled straw, hay, etc. is being tested in Pima County, Arizona, and building codes are being revised accordingly, as another example of synecotecture (Bryce 1997).

The term "Agrostis" has now to be used in this context. It would be misleading to refer to the "National Grass Day Foundation" in that the worthy word "grass" has been stolen by the drug subculture and is, henceforward, ever denied its proper meaning. Agrostis [agrostology: that branch of botany that treats of grasses (Anonymous 1966)] is probably the most appropriate term for this precise proposal.

Most immediate in the purposes of this complementary day of celebration, however, is the introduction of grass economy to the city.

I always explore with pleasure any abandoned car-park, railroad yard, and industrial wasteland, to discover what forbs and grasses are emerging in triumph over the concrete and sour-soils. Usually the initiatives are taken by the coarser forbs, commonly known as "weeds," while the less aggressive grasses follow.

I recommend that the process of grassification or "agrostification" of cities be explored. I am sure that J. Sterling Morton would approve, because there is an obvious agricultural and arboricultural significance in the processes of succession. Where grasses lead, trees will follow in time.

Emiel Christensen (1895-1988)

The second hero is very different. Some of you might have had the privilege of knowing that buoyant soul, warrior of the First World War, architect, planner and vintner whose blending of American and Chilean wines was as refined as his appreciation of the Nebraska landscape.

No stranger could be more fortunate in having Professor Emiel Christensen (of Columbus, Nebraska) as his instructor, and be entertained by him and his like-minded family on the character and history of Nebraska. This privilege would occur regularly, irrespective of the weather, on his 30-acre demesne. This land, which he had bought with a neighbor in 1954, lay on a north-facing escarpment overlooking the Platte Valley, and had been overgrazed and pillaged. With judicious care, he watched the interplay of climate and vegetation as the eroding ravines and gullies gradually filled with varieties of vegetation in the self-sustaining processes of revival.

In 1965, the acreage known to all as PaWiTo (after the initials of the emerging generation) contained 61 species of trees, 32 species of shrubs and 17 different vines, as well as a wide variety of self-established grasses, mosses, forbs and wildflowers.

The essence of this exercise was to observe the everlasting marginal conflict between grassland and shrubbery, to see which would prevail, and in what topographic positions.

This most eloquent demonstration revealed that grasses would yield to the trees and shrubs. It was a revelation, also, of the rapidity of change. Hard may be the prairie climate, but delicate is the soil.

He accommodated his guests as troglodytes in 3 hand-wrought caverns (geotecture), from the loess-like soil of the escarpment, each provided with internal fire-places, their chimneys rising through this earth. Eventually these were supplemented by a semi-submerged chalet (topotecture), where the central fire-place and chimney were carved free-standing from the earth removed to form recessed bed-chambers.

This demesne was the scene of much merriment, instruction and stimulating entertainment. On one occasion the gathering included Secretary of Agriculture Orville Freeman, who was anxious to meet this renowned Nebraska Sage. They were joined by Governor Frank Morrison who conducted a videotaped exchange of opinions and experiences in his exceptional brand of light-hearted legal sagacity to the enjoyment of all assembled.

PaWiTo quickly became an educational treat and an intellectual retreat focused upon prairie ecology.

To Emiel Christensen, the soil was sanctity personified. His courtesy arouse from the indigenous Indians, among whom he had attended school on the Omaha-Winnebago Reservation, as the only non-Indian child, while he spoke only Danish.

His descriptive eloquence, wit and sharpness of judgment were an inspiration, commemorated in his pioneering planning and concern for the individual towns and settlements throughout the State, especially in their differences, even when they appeared to be so similar. He founded the annual Nebraska Community Betterment Association and Contest. This was designed to emphasize community distinctions, to teach the substance, subtleties and beauties of the prairie as it differed from region to region. This Contest continues in his honor even as the urbanization increases and the prairie retreats.

He suffered severely during the final German offensive in 1918, but revived to turn his architectural training to many practical activities throughout the Great Depression with his concern for the fragmented Indian peoples. Perhaps his most lasting expression of endeavor is his vibrant book *Created Pawns or Creative Partners* (Christensen 1961). This very expressive title reflects not only his persuasive personality, but especially his appreciation for the human response to landscape disciplines. The Doyen Emiel Christensen personifies Nebraska in terms of humanity in the context of the spiritual influence of this landscape.

Lawrence Enersen (1915-1986)

My third figure is the distinguished architect, planner, landscape designer, Lawrence Enersen. He lived in Lincoln, Nebraska, and the great boulevard of the Capital (Enersen Avenue) is named for him.

Mr. Enersen's especial enthusiasm was expressed in trees. He believed them to be essential to the urban fabric, in back yards, parks and especially along streets. He was as determined on their place in the city as were his pioneer-predecessors who planted their original communities so lavishly. Lincoln is, in my assessment, the best tree-dressed city in America. In consequence, the downtown area has retained its economic vitality and its inhabitants. It remains a lively social center to the delight of citizens and visitors alike.

He had the most confident eye for topographical advantage and flair for siting his buildings, as sure as that of the early settlers.

His landscape 'touch' was instinctive, and sensitive to the disciplines of the historic Chinese feng-shui design disciplines, now becoming so popular.

It is someone like Mr. Enersen whom I would trust to fulfill my proposition for "prairiefying the cities." His planning and plantings around the Capitol in Lincoln, are exemplary. But all was done at ground level, and now, as the ecological crises intensifies, elevated roofs require our attention in terms of synecotecture.

Perhaps some of you can provide examples of synecotectural design which might be examined in detail in support of my prognostication. I deliberately use a medical term here because the operations proposed are a matter of health (human and ecological), as well as an exercise in aesthetic appreciation in the obvious beauty of grass and grasses.

No one doubts the nobility of trees. But the story of grasses, season by season, in the mass and as isolated specimens, is still to be realized as a popular pleasure. The humorous references to "watching the grass grow" is now an urgent psychological recommendation amid the hysterical pace of modern commitments.

SYNECOPOLITAN PLANNING

Walls

Because the issue, here, is primarily the use of grasses, I shall not concentrate upon the covering of walls, and the variety of climbers which are appropriate, the ivies (*Hedera helix*); the honeysuckles (*Lonicera tragophylla* and *L. americana*); and the ubiquitous Quinquefolias (*Parthenocissus tricuspidata* and *P. henryana*, and *Nephrolepsis exaltata bostoniensis*), and as already noted, the 17 species of vines growing at PaWiTo.

Roofs

The terms synecotectural design and synecopolitan planning arise from synecology, the study of animal and plant community interaction. It would seem that mankind is the only species which denies and defies this fundamental system of interactive support. Our insatiable determination to dominate and exterminate anything which irritates, (insects); which offends the sight (dandelions); which trespasses (deer) with a profound disregard for the essential values of biodiversity represents a monument to human ignorance and consequent folly.

In recognition of the prevailing reduction in the photosynthetic process, whereby productivity is hindered, the need to cultivate the vitality of biodiversity is now a critical social obligation. I maintain that most structures domestic, commercial and industrial, should contribute to the reversal of this disastrous trend by offering their roofs for the support of vegetation.

As animals and plants are endowed with protective defenses against the elements, we have devised the wall and the roof. The quantity of these provisions is now so extensive as to affect the microclimate, as any inhabitant of Chicago or Mexico City will confirm. Modifications are required and this is a matter of design. These are now provided in the form of air-conditioning, cooling and heating on an ever-greater scale and cost. But this deals only with interiors, whereas the problems arise on the outside due to the reflection from the hard streets, building materials, and especially from the roofs.

In response to this design problem, architectural practice requires total reconsideration and logical analysis as devised by Frank Lloyd Wright in the form of his overhanging roofs keeping the walls in shade prior to the use of mechanical refrigeration.

As the current advertisements of Archer Daniels Midland imply, the prairie soil's fertility and land-use crises is of ever greater importance as the world populations increase.

I have chosen a brief list of particular issues vital to planning and design revisions as the basis of a fresh "prairie esteem," in terms of synecotecture, in which the contribution of various grasses is required, and your critical encouragement is of the greatest value.

The oldest example of practical synecotecture is, perhaps, the hanging gardens of Babylon, ca. 800 BC, where selected vegetation was used on roofs and in courts as air-conditioners. These created the necessary variations in character to cause air movement, aromatic effects, and to maintain humidity, in addition to the thermal consequences of sun exposure and shadow. The newest example is a Victorian factory, ca. 1855, in Leeds, Yorkshire, where sheep-cropped grass roofs maintain consistent humidity for Egyptian tobacco storage and processing.

In particular, I seek your critical responses on the cultivating of grasses on roofs, near flat and sloping.

The essence of this task is water: supply, control and drainage. This water can be regulated under manual or automatic settings according to humidity required by the grasses chosen, and the anticipated rainfall as an extension of the domestic, commercial or industrial supply, under direct or remote control, season by season.

Structural economics.—The economics of a synecotectural roof is critical to the entire design concept. The weight, beyond snow loading, must be reflected in the foundation, column, and beam costs, and this depends upon the purpose of the structure. These structural costs may be amortized over a decade against maintenance economy.

Maintenance.—If the constructional details have been faithfully fulfilled, the constant repair of roofing materials under stress by day and night, summer and winter expansions and contractions will benefit from the consistent thermal protection offered by grasses and their root entwinements, by soil, and by the humidity they retain. The reduction in costly hard roof-surface maintenance will compensate for the higher structural costs, compared with conventional construction. Even the covering of the roofs by standing water should be assessed for comparative economy.

For several years, I observed a normal commercial flat-roof in Lincoln, Nebraska, on which the drainage had become blocked. Reeds and rushes had grown in sufficient density to entice a pair of Mallards to breed and rear their brood on the food to be found in the confined water which, eventually, dried up in the summer heat.

I visited an 8-story, flat-roof, waterless in this instance, on the outskirts of St. Louis on which a pair of Canadian Geese hatched their young. These goslings had to be corralled by the local fire-brigade personnel almost immediately after hatching. They delivered them to their anxious parents awaiting their arrival at the lake's edge. The fire guards had watched where the geese flew for watering and feeding at some distance from their roof nest. These geese appreciated that the rooftop was safer than the ground of a public park with its hazards from feral cats, dogs and children. Goslings cannot fly for 4 months and geese cannot convey food or water. We should no longer build for human convenience alone, but should acknowledge obligations to other species in conformity with general synecological disciplines.

Soils.—Since roof-loading is so critical, I have recommended exploratory soil depths of some 4 inches. This requirement involves the experimental opportunity of careful selection and mixing of soils. These soils and their microbiological components are compromised if they form part of the ground. The roof-site permits better control over insect, worm and microbial population densities, required for ever closer analysis as experiments continue.

The desired absence of chemicals, insecticides, pesticides, herbicides and fertilizers can be better guaranteed, or applied with exacting accuracy for testing purposes. Not only for scientific plant study but, most important, the resulting drainage is readily accessible for examination reuse, or for effective treatment before disposal. In this way, ground-water protection may be better assured (with respect to another Nebraska initiative, the Groundwater Foundation). Water economy is as important as is soil quality and stability.

Rootings.—For reasons of rainfall irregularities and ground-water depths, most prairie grasses are long-rooted. In consequence, I am advised that there is no benefit in denying this root characteristic radix by planting such species in only 4 inches of hot or frozen soil when their natural inclination is to search for cold earth and water many feet below. Roots will seek water wherever available and in consequence such deep-roots may spread horizontally within the soil layer and will form, in time, a dense thatch, thereby improving thermal protection for the building, summer and winter. The emerging heat from the building interior may reduce frost damage to the horizontal roots.

Clearly, this is a matter of experiment and testing, but I am not aware of any such exploration with various grasses under test in varying depths of selected soils throughout severe prairie summers and winters. While some grasses will respond better than others, the tall Johnson grass (*Sorghum halepense*), the dense grama grass (*Bouteloua* spp.), or the varieties of buffalo grasses (*Buchloe* spp.) will all yield information of value in roof cultivation, or elsewhere.

Here is an opportunity for agrostis experimentation as well as experimentation in soil composition, chemical application, soil microbiological populations, and the responses of grass adaptations. Furthermore, there would be opportunity to examine grass distortions, in densities and varieties, in their mix with forbs, and their synecological contributions. Their relative values in photosynthetic yield and in detritus should be known, and I assume that such experiments are being done routinely.

Similar questions arise over the use of leguminous plants (vetches and clovers) necessary for the encouragement of urban bee-fields, especially important at this period of global crisis in apiculture, upon which so much depends.

Rooftop grasses will be significant, also, in the crisis of grass-related aviculture, in that the recorded reductions in small-bird populations, larks, and grass-feeding finches are significant with respect to insect plagues.

Roofs provide seclusion and, unless easy access is provided, they become forgotten, hidden territories, which offer security for the ground-resting migratory birds and for ground-nesting species now in increasing danger from chemical poisoning. The roof can become a significant instrument in human synecological practice.

All these questions arise again when the slope of the roof is considered. At what pitch will these same grasses prosper or perish? The angle of sun exposure is a vital issue as any banked lawn owner will confirm. What surface design precautions must be taken to hold the soil before erosion reduces the benefits of grass cover, and which of these conditions justify experimentation using commercial sods and turf?

Person/plant proxemics.—Finally, there is another aspect of plant covered roofs to be explored. It concerns the advantages of person/plant proxemics and the reasons are psychological.

The pace and pressures of life produce an ever increasing demand for relief: sports facilities, Disneyesque diversions, changes of scene, cruises and other timely but costly pursuits. The simple value of pottering with plants is therapeutic, a domestic pastime of known health benefit. Any form of urban phyto-psychotherapy is to be recommended, and the benefits of roof gardening are gaining attention. I commend the value of roof-fields, where the labors of cultivation are left largely to the plants themselves, who may be depended upon to exude tranquility and quietude while providing endless entertainment as they pass from sprout to bloom to seed with effortless grace, whether dew-dusted or dry.

Such roof retreats are provided in London for wheel-chair patients, where the earth is raised in troughs so that it is within easy reach of those afflicted. Their pleasure and therapeutic benefit can be imagined. While flowers are usually the focus of attention, the flourish of grasses and their seed-heads is only a matter of educated fascination. Rose fanciers, including Winston Churchill (whose full Citizenship of Nebraska made possible his Honorary Citizenship of these United States) are a much respected brand of humanity. But grass fanciers (agrostiphiles) may emerge as an enviable and balanced political force.

Education.—Synecotectural design is no less a matter of education than of economic prudence and design innovation. The instructional value of the acres of shopping-center roofs, school roofs, and university roofs is already available and waiting to be used as 'open' classrooms. These classrooms can be used as demonstration grounds, herb gardens, bee-fields, even shrub yards and vegetable beds to encourage the citizen in therapeutic pastimes.

The experience of British war-time allotments can be revived, not only for food production, but for reasons of individual exercise, health and urban phyto-psychotherapy.

I am sure that there is magic to be observed on any roof planted with prairie grasses which will adapt, survive, and then flourish in a demonstration establishing an agrostological equilibrium, a balance between the characters involved and the particularity of space available. Where can the distracted human gain composure from the bewilderment of place and circumstance if not on the roof, the traditional place of retreat and isolation?

CONCLUSION

The ultimate factor confirming prairie grasses as effective, productive, roof coverings is energy. In this case it is agrostis-energesis: that measurable vitality which stimulates the individual in the presence of grass, even as he or she may be revitalized by the presence of the sea. Again, this is an educational issue, with strong health and psychological importance.

It is time for the prairie forces (natural and human) to assert themselves in the promotion of urban well-being with grasses selected from the deserts of Chihuahua to the wilderness of Alberta, in retaliation for the damage done to the prairie scene by creeping urbanization. The propaganda value of such a surprise attack upon the city, in the form of roof fields, allotments and gardens, according to size, is beyond estimate and should be tested without delay.

Nowhere in the world is grass more valued and pampered than on the American golf course and on suburban lawns, and I would wish to see this enthusiasm in agrosticulture extended to include prairie grasses in their infinite and vigorous variety carrying their vitality to and through the great central cities of North America, from Edmonton to Monterey.

It is time, indeed, that cities gained relief from their self-imposed tyranny of hard surface reflections and the consequences, both climatic and emotional. The simple act of enclothing structures with indigenous vegetation, on walls and roofs, is most natural. Nebraska has the material in its various grasses; it has the tradition, the sod-house; it has the experiences as exemplified by the works of Morton, Christensen and Enersen.

The will to retaliate against the spreading urbanization will bring aesthetic relief, microclimatic, economic, and wildlife benefits, and national reputation as well. It is natural that Nebraska should take lead in the practice of synecological design upon its own communities. It would be a celebration of its own magnificent scene, the Nebraska prairies, upon this millennial threshold, heralding a century of Prairie Esteem.

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EXPANSION OF EASTERN RED CEDAR IN THE NORTHERN FLINT HILLS, KANSAS

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Abstract: Woody expansion into grasslands has been documented across the western United States. Possible causes include decreased burning, increased grazing by cattle, and regional climate change. In the Flint Hills of Kansas, eastern redcedar (*Juniperus virginiana*) is expanding into many upland prairie sites. We used a supervised classification of Landsat Thematic Mapper imagery from 1997 to identify the extent of closed canopy redcedar forests in 7 counties in the northern Flint Hills. We characterized these forests by soil type and related woody expansion to socioeconomic factors using a GIS. Closed canopy forests occupy 5421.5 ha within the 7–county area with 84% of these forests occurring in Riley and Pottawatomie Counties. Redcedar forests were more prominent on loamy upland soils than on other soil types. Redcedars were more prevalent in counties with large cities and near manmade structures such as reservoirs. Human population increase over the past 2 decades explained 81% of the variance in redcedar density.

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Key words: GIS, *Juniperus virginiana*, Landsat Thematic Mapper imagery, upland prairie, woody expansion.

In North America, woody species encroachment into grasslands has been documented from Idaho (Burkhardt and Tisdale 1976), southern New Mexico (Schlesinger et al. 1990), in Kansas and in Oklahoma (Owensby et al. 1973). Causes for this land-cover change in recent years include intensive grazing by livestock (Schmidt and Stubbendieck 1993), reduced fire frequency and intensity (Bragg and Hulbert 1976), regional and global climate change (Schlesinger et al. 1990), and combinations of these factors (Archer et al. 1995). Even early settlers in the tallgrass prairie region of North America observed that dense forests grew up around European settlements when all fires were suppressed near homes and other buildings (Wells 1819).

The Flint Hills region of east-central Kansas is approximately 70 km wide and extends from the Kansas-Nebraska border south into Oklahoma (Knapp and Seastedt 1998). This area today contains 1 of the last open expanses of bluestem or tallgrass prairie on the North American continent. In the northern portion of the Flint Hills, invasion by woody species, especially eastern redcedar (*Juniperus virginiana*), is a problem (Owensby et al. 1973). Eastern redcedar has 1 of the widest geographic distributions of any tree on the North American continent with populations recorded from Florida to Canada and westward to Kansas and Oklahoma. Across the tallgrass prairie region, 82.6 to 99.9% of the tallgrass prairie has been lost (Samson and Knopf 1994) and woody invasion, especially redcedar, could further jeopardize this endangered ecosystem. Redcedar invasion has several impacts in the Flint Hills region. Mature redcedar forests (30-60 years old) tend to form monoculture stands with few other woody species present. Under redcedar canopies, prairie species diversity declines dramatically (Kaul and Keeler 1980). We personally have seen that with canopy closure the forest floor of redcedar woodlands is often bare ground with few herbaceous species present.

Along with the decrease in species diversity is an obvious decrease in herbaceous biomass production, with almost no biomass produced under a closed canopy (Arnold 1964). This has severe consequences for the livestock industry, because sites that have been heavily invaded by redcedars cannot be stocked at their former rate, or they may be taken out of production completely. These results could have economic repercussions for the entire region since Kansas is 1 of the largest beef producing states in the United States.

To examine large-scale spatial patterns and processes across the Flint Hills region, satellite remote sensing is the most economical and logical tool. For example, the U. S. Landsat satellites sample a 185-km by 185-km area and most importantly resample the entire earth's surface at a return interval of 16 days. In addition, there are extensive archives of satellite imagery dating back to 1974 which allow researchers to study changes in broad-scale landscape patterns over the period of decades (Green and Sussman 1990).

High precision land cover classification is often difficult to do using only a single date of satellite imagery. Recently, researchers have used multi-temporal (multi-seasonal) imagery to discriminate between grasslands and agricultural areas and to identify specific crop types (Price et al. 1997). This method exploits the differences in phenological (green-up and senescence) patterns between different plant species and plant communities to more accurately discriminate between the various land cover types. We believed that this method should be useful in identifying redcedars in the Flint Hills since this is the only coniferous species in the area.

Objectives

Our study had 3 major objectives:

1. Map the locations of closed canopy redcedar stands across the northern Flint Hills using multi-temporal satellite imagery.
2. Determine whether these stands were distributed at random across the landscape.
3. Determine whether the modern-day distribution of redcedar stands can be attributed to socioeconomic factors within the area.

This study was designed to analyze closed canopy stands. These techniques are not adequate for identifying the pastures sparsely covered with isolated redcedar trees.

STUDY AREA

In the tallgrass prairie of the Flint Hills region the dominant grasses include big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon [Schizachyrium] scoparius*), and Indian grass (*Sorghastrum nutans*). The region is characterized by gentle to steeply rolling hills, shallow and rocky upland soils, and distinct benches of limestone and shale sediment which are visible on many hillsides. Deep permeable soils can be found in the wide valley along major drainages. Gallery, or riparian, forests dominated by bur and chinquapin oak (*Quercus macrocarpa* and *Q. muehlenbergii*) and hackberry (*Celtis occidentalis*) can be found along many of the seasonal and permanent streams. This study was limited to a 7–county area in the northern Flint Hills (Fig. 1) which could be fully encompassed in a single satellite image (path 28, row 33). Included in the study area are the Konza Prairie Research Natural Area in Riley County and the Tallgrass Prairie National Preserve in Chase County.

METHODS

Two Landsat Thematic Mapper (TM) images of the northern Flint Hills were used to identify closed canopy redcedar forests across the 7–county study area. TM imagery consists of 7 bands of spectral data with a pixel size of 30 m. All image processing was conducted in ERDAS Imagine 8.3.1. Bands 3 (0.63-0.69 (m), 4 (0.76-0.90 (m), 5 (1.55-1.75 (m), and 7 (2.08-2.35 (m) were used for this analysis. A multi-temporal or multi-seasonal approach was used. Images from 3 March and 11 September 1997 were registered to each other using 34 ground control points (GCP) and a nearest neighbor algorithm with root mean square (RMS) error of 0.54. This 2-date image was then georeferenced to Universal Transverse Mercator (UTM) coordinates. In the March image, prairie and deciduous forest were senescent and redcedar forests and agricultural fields (mostly winter wheat) were the dominant source of high reflectance in the infrared region of the spectrum. In the July image the redcedar forests appeared darker as the chlorophyll reflectance was dominated by the deciduous trees, grasses, and crops. By exploiting these differences it was thought that a higher classification rate was attainable than if either image was analyzed separately.

To identify closed canopy redcedar forests, a supervised classification with a parallel piped algorithm was used. In a supervised classification it is assumed that the researcher has some knowledge of the study area. The researcher extracts pixels that represent a specific land cover type and uses these pixels to "train" the computer to recognize other areas with a similar spectral signature. The parallel piped algorithm uses simple Boolean "and/or" logic to determine which land cover-class a pixel should be assigned (Jensen 1996). We used 273 pixels from 3 sites that were previously identified as closed canopy forest to train the classification.

Once this coverage was generated, all polygons (groups of contiguous pixels) < 2 ha in size were identified by the computer and removed to reduce the "noise" in the coverage. Forests smaller than 2 ha were difficult to identify when collecting ground-truth data. For final presentation a 3 by 3 pixel majority filter was applied to the coverage to "smooth" the polygons.

During June and July 1998, the accuracy of the classification was checked by extensive field surveys in Riley County and Pottawatomie County, where the majority (84%) of redcedars were identified on the imagery. Using these data, the user's and producer's accuracy were calculated. The user's accuracy is a

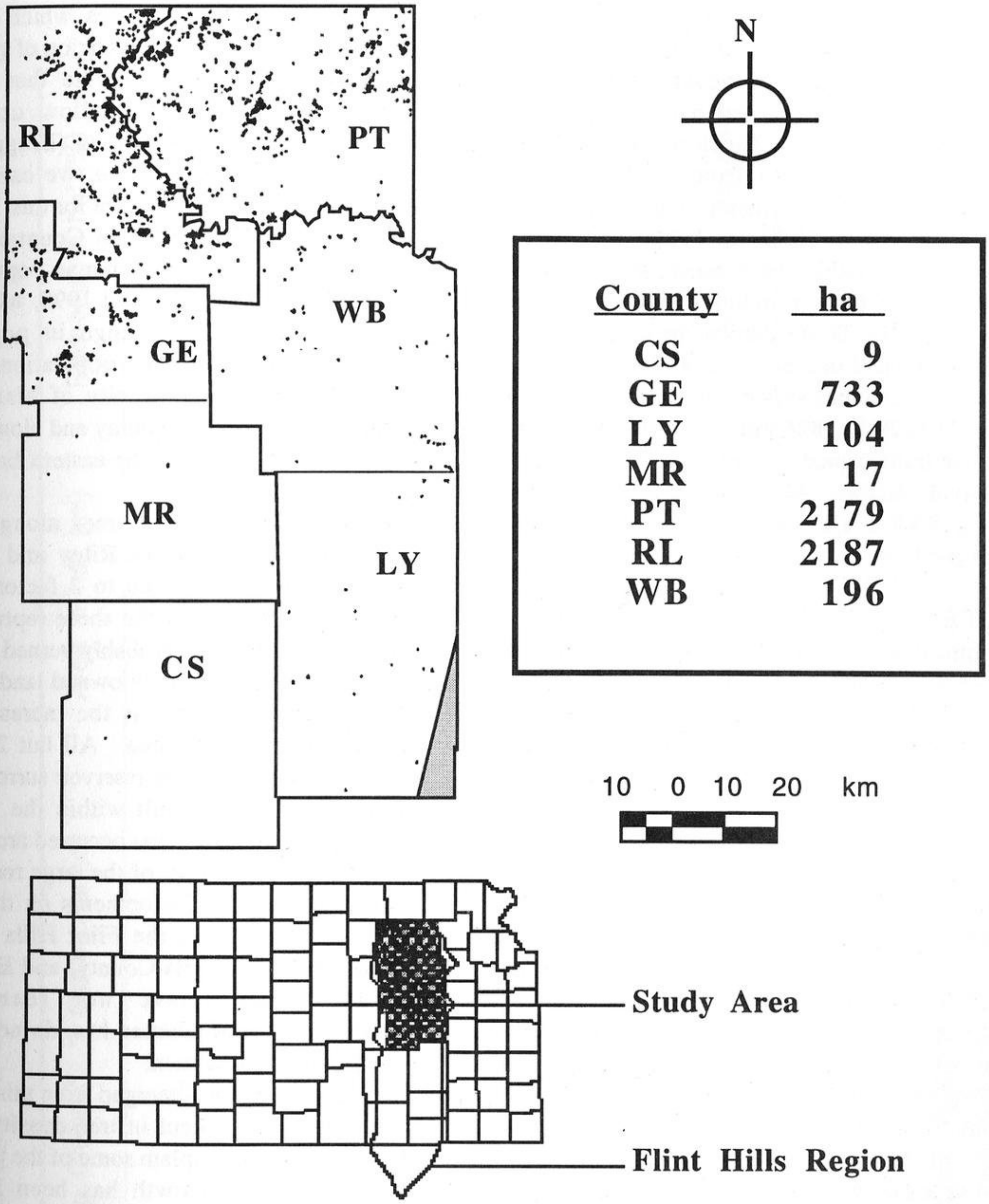

Fig. 1. GIS coverage of the study site showing the distribution of redcedar forests across the study area. Black areas represent closed canopy redcedar forest. The gray triangle in the southeast corner of Lyon County (LY) indicates no data available for this area.

measure of commission error and is the probability that a pixel in a given category on the map actually represents that category on the ground. The producer's accuracy is a measure of ommission error and is a measure of how well an area can be classified (Congalton 1991).

Riley County was isolated from the larger study area for more detailed study. This county had the highest density of redcedars and in addition had an extensive collection of digital GIS coverages such as Soil Survey Geographic Data Base (SSURGO) certified soils coverages. The redcedar forest coverage was overlaid onto a soils layer using Arc/Info. A chi-square test was then used to test whether redcedar forests are distributed randomly on the landscape relative to soil type. For this test the proportion of soils across the county were the "expected" variable and the actual distribution of redcedars by soil type was used as the "observed" variable. Under a null hypothesis, it would be expected that the proportion of soil types across the county would be equal to the proportion of soil types underneath redcedar forests.

To examine the impact of socioeconomic factors such as population growth from 1970 to 1990, population size in 1990, housing density in 1990, housing starts from 1970 to 1990, and cattle production, these variables were tested for correlations to redcedar density (data from http://www.ukans.edu/cwis/units/IPPBR/). To standardize the data, redcedar density was adjusted to a percentage of each county. The sizes of the counties varied from 103,553 ha (390 miles^2) to 219,229 ha (826 miles^2). Percentage data was angular transformed and regressed against the socioeconomic factors. All statistical analyses were done using SAS v 6.12, and significance was expressed at $p < 0.05$.

RESULTS

An initial survey of 28 polygons from the Manhattan area using single date (11 September) imagery yielded a classification accuracy of only 74%. The classification accuracy for identifying closed canopy redcedar forest with multi-seasonal imagery was 90% (46 of 51 polygons) and 94% (46 of 51 polygons), producer's and user's accuracy respectively (Fig. 1). Riley County had the highest coverage of redcedars with 2187 ha (5270 acres), covering 1.37 % of the county, and Chase County had the lowest coverage of redcedars with 9.4 ha (23 acres) covering 0.005% of the county (Table 1).

Redcedar forests are not distributed randomly across Riley County as the chi-square test for distribution of redcedar forests by soil type was significant ($X^2 = 193.3$). Seven of the 8 soil types with high percentage of redcedar forest cover were classified as loamy uplands (6 soil types) or as stony breaks (1 soil type). None of the socioeconomic variables revealed a significant relationship between the variables and redcedar density. However, human population size change from 1970 to 1990 was significant ($p < 0.01$, $r^2 = 0.81$) with the amount of redcedar cover in 1997 (Fig. 2).

DISCUSSION

Many, if not most, grassland sites in eastern Riley County have some redcedar trees present in them. Redcedars are also prevalent along many highway rights-of-way. The redcedar stands identified in this study were just the end point of a continuum from treeless upland prairie to closed canopy forest. These mature forests provide a plentiful source of seeds into surrounding prairies, which can exacerbate the problem of woody colonization of grasslands.

These results demonstrate that redcedars do preferentially occur on shallow upland soils as described in previous studies (Bragg and Hulbert 1976). Based on these data, we cannot, however, determine a causal mechanism for this.

Riley and Pottawatomie Counties have shown the most dramatic rate of human population growth (Table 1) between 1970 and 1990, while 3 counties have had almost no change in population size. Within Riley County, the population increase was concentrated around the city of Manhattan in the southeast corner of the county and along Tuttle Creek Reservoir, which forms the eastern boundary of the county.

The high density of trees along Tuttle Creek Reservoir, which divides Riley and Pottawatomie County, can be attributed to 2 factors. The small redcedar patches along the shore represent federally owned property that is probably burned less frequently than surrounding privately owned lands. The second (possibly larger) factor is the increase in housing developments in this area. All but 2 of the larger redcedar forests along the reservoir surround residential developments were built within the last 30 years. The same phenomenon has occurred around the city of Manhattan, where most of the large redcedar patches surround housing developments on the edge of the city. Other cities in the Flint Hills area, such as Council Grove (Morris County) and Emporia (Lyon County) which have not seen the rapid suburbanization Manhattan has, do not have mature stands of redcedar present.

One pattern that emerged from this study was the north to south gradient in tree density. Population demographics can explain some of the patterns we see since population growth has been largest in the northern counties. Different land use practices such as grazing rotations, extent of burning, or the historical plantings of redcedars as windbreaks or for fenceposts may also help explain some of this pattern. To date, we have not found historical data to test these ideas.

The spatial pattern of redcedar forests could be examined on 2 different spatial scales. At the large scale of the county there was a significant relationship with human population size. At a smaller scale, within Riley County, redcedar forests are more prevalent along the reservoir and the edge of the city of Manhattan: the 2 areas with the highest rates of development.

Table 1. List of socioeconomic factors thought to be in part responsible for redcedar expansion. The 2-letter code after each county name is the same code used in Figs. 1 and 2.

County	Houses[a]	Pop. Change[b]	Cattle Change[c]	Area in ha[d] (mi)	Redcedar in ha[e] (%)
Chase (CS)	25	-387	-4700	199,173 (750)	9.4 (0.005)
Geary (GE)	3201	2342	800	103,552 (390)	733.1 (0.708)
Lyon (LY)	3332	2661	-5900	219,228 (826)	103.9 (0.047)
Morris (MR)	241	-234	-100	179,975 (678)	16.5 (0.009)
Pottawatomie (PT)	2159	4373	-5700	220,789 (831)	2174.8 (0.985)
Riley (RL)	8003	10351	-4800	159,332 (600)	2187.4 (1.373)
Wabaunsee (WB)	293	206	-2600	204,855 (771)	196.4 (0.096)
Total				1,286,907 (4,846)	5421.5 (0.421)

[a]The number of new houses built in each county between 1970 and 1990.
[b]The increase in population size between 1970 and 1990.
[c]The change in the number of cattle produced in each county.
[d]The area of each county in hectares and square miles.
[e]The coverage of redcedar in each county and the percentage of that county.

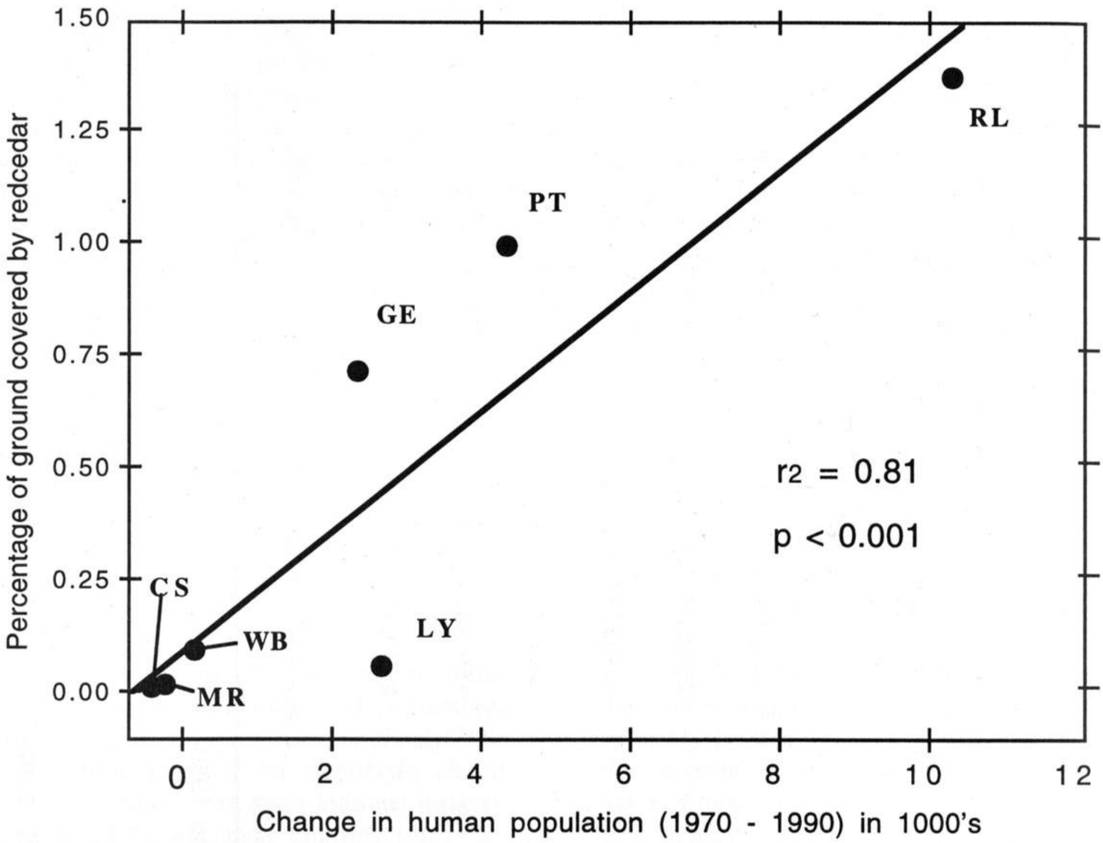

Fig. 2. Regression of population growth by county between 1970 and 1990 and percentage of the county occupied by closed canopy forest.

CONCLUSIONS

In the 7 counties that comprise the northern Flint Hills of Kansas satellite remote sensing identified 5421.5 ha (20.4 square miles) of closed canopy redcedar forest. Multi-date imagery improved the accuracy of redcedar forest identification by 20% over single date imagery. Riley and Pottawatomie Counties accounted for 84% of these forests. Redcedars are not distributed randomly across Riley County but prefer shallow, upland soils. There was a significant relationship between human population growth from 1970 to 1990 and redcedar density at the county level.

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THE BOTANICAL INTERFACE BETWEEN TALLGRASS PRAIRIE AND A SMALL PRAIRIE TOWN

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Abstract: This study examined the effects of nonindigenous plants dispersing from a source population in a small prairie town (Matfield Green, Kansas) into the upland tallgrass prairie. Sources of plant introduction were related to early cattle trails through the community, railroad and stockyard locations, gardens, cultivated fields, livestock and wildlife activity. Dispersal of naturalized introduced plants followed roadside corridors out into the prairie. Introduced plants were grouped in life-history classes of winter annual forbs and grasses, summer annual forbs and grasses, perennial forbs and grasses. Native prairie plants were grouped as perennial forbs and grasses. Distribution of introduced plant groups formed a gradient from high abundance in the townsite to low abundance in the prairie. The distribution of native plant groups formed a reverse gradient from the prairie to the town. Introduced plant groups were distributed along truck trails well out into the upland prairie but had not yet invaded the surrounding grassland.

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Key words: agricultural fields, cattle trails, Kansas, Matfield Green, native prairie plants, nonindigenous plants, rural towns.

Roadways are corridors of distribution for introduced species that invade native prairie ecosystems. Human activity centered in and around rural townsites creates a source population for exotic and weedy species from gardens, lawns, parks, and adjacent agricultural fields. These species may naturalize and migrate into the native vegetation and establish on sites where plant cover has been destroyed or weakened (Radosevich and Holt 1984). Some of these species are able to compete successfully with native plants, resulting in increased species diversity, but a decreased abundance of native species. Species with invasive potential can spread vegetatively or by seed into new habitats and eventually even displace native species (Young et al. 1972, Mack and Thompson 1982, Mack 1986, Mooney et al. 1986, Pyke 1990, Schmitz et al. 1997).

Many of these nonindigenous invaders are considered to be weedy species and can be classified by their life histories as winter annual forbs and grasses, summer annual forbs and grasses, and perennial forbs and grasses.

Winter annual forbs that have become widespread include members of the family Cruciferae; bushy wallflower (*Erysimum repandum* L.), penny cress (*Thlaspi arvense* L), peppergrass (*Lepidium densiflorum* Schrad.), shepherd's purse (*Capsella bursa-pastoris* (L.) Cyr.), and tansy mustard (*Descurania pinnata* (Walt.) Britt.).

A winter annual grass, Japanese brome (*Bromus japonicus* Thunb. ex Murr.) is a species with invasive potential that is well established in towns and along roadsides.

Introduced forbs that are summer annuals are widely distributed species such as hedge parsley (*Torilis arvensis* (Huds.) Link.), kochia (*Kochia scoparia* (L.) Schrad.), and rough pigweed (*Amaranthus retroflexus* L.).

Crabgrass (*Digitaria sanguinalis* (L.) Scop.) is an introduced summer annual grass, and is a widespread lawn and agricultural pest.

Non-native perennial forbs such as common chicory (*Cichorium intybus* L.), curly dock (*Rumex crispus* L.), and field bindweed (*Convolvulus arvensis* L.), and a non-native perennial grass, johnsongrass (*Sorghum halepense* (L) Pers.) are also well established along roadsides.

These invaders are disseminated along roads throughout the tallgrass prairie and well into the prairie by ranch vehicles, livestock, and wildlife. The patterns of dispersal follow established routes of human activity, e.g., railroad right of ways, ranch roads, truck and cattle trails, cattle feeding sites, and stock ponds. Plants follow these probable dispersal routes into the prairie and some of them may establish populations that persist.

Nonindigenous species should be more abundant at their townsite source and should be expected to decline in abundance along roadsides that border the prairie uplands. My study identified the patterns of distribution of these plants within the townsite of Matfield Green, Kansas, the adjacent agricultural valley, the prairie slope, and the prairie upland. I assessed the influence of these patterns on the species composition of the prairie.

STUDY SITE

Matfield Green is a small rural town located in the Flint Hills grazing region of east central Kansas. The townsite has maintained a human population of from 200 to 50 since the 1880s. Human activity overtime has created opportunities for the introduction of a number of plant species that are not native to the region. Deliberate or accidental introductions have occurred from such sources as agriculture, livestock, ornamental plants, and plants that were used for soil conservation and wildlife habitat (U. S. Congress 1993). Human activity disturbs existing plant communities and disturbed sites offer new habitat to colonizing species (Tilman 1990).

In addition to the obvious effects of disturbance on native plant life in the townsite and adjacent farmland, Matfield Green experienced two historical events that facilitated the invasion of nonindigenous plants. The first of these was the Sante Fe Railroad's mainline track bordering the town on the west side from north to south. Railroad beds are wayside avenues for the dissemination of transient seeds. The coming of the railroad promoted the shipping of cattle into the area for summer grazing (Wovel 1980). The second event was the practice of driving the cattle, newly arrived from the southwest, from the railroad yards, through town, to their summer pastures on the prairie uplands. This practice continued until the late 1950s when trucks replaced the railroad as primary transportation for cattle (Biery et al. 1998).

The South Fork of the Cottonwood River forms the eastern boundary of the town. The river valley is 3 km wide at this point and is mostly developed for agriculture. The tallgrass prairie begins at the edge of the valley and rises in an 8° slope that is 3 km wide and terminates in an extensive upland prairie. The topography to the west of the town is similar except that no valley habitat is present. County roads divide the 4 habitats on both the east and west sides of the townsite.

METHODS

Strip transects were established parallel to east-west roads through each of 4 habitat types: Matfield Green townsite, agricultural valley, prairie slope, and prairie upland. A transect was divided into 10 segments for each habitat type. Each transect was run twice in March and July during the growing season of 1997. The line was continuous for 12 km to the east and for 9 km to the west. Each transect was positioned in the roadside vegetation 0.5 m north of the road edge to minimize the effect of edge disturbance. I recorded the presence of introduced species in each segment of the 100 m^2 transect and calculated a percentage of occurrence for the habitat transect.

Species in each habitat were classified by similar life-history characteristics into 3 groups. The first was winter annual forbs and grasses: species that germinate in the fall and produce seed in the early spring. The second was summer annual forbs and grasses: species that germinate in the spring and produce seed in the late summer. The third group was perennial forbs and grasses: long-lived species that have annual reproductive events.

I determined the frequency of occurrence for plants in each life history class present in each of the habitat types.

I also recorded species presence in each category by sampling paired transects placed parallel to each other along established truck trails in the prairie upland habitat. One transect was located on the trail and the other was 5 m away in the prairie vegetation. The trail transects were placed at 90° angles to the county road to form an extension from the roadside transects and were designed to measure vectors of plant distribution into the prairie. Nonindigenous plant species that are represented by life-history groups are shown in Table 1. Plant nomenclature follows McGregor et al. (1986).

RESULTS

I recorded 34 nonindigenous plant species on all transects through the 4 habitat types (Table 1). Abundance of introduced annuals in all life-history classes was highest in the townsite and lowest in the prairie upland (Fig. 1). Forbs and grasses from all annual classes declined across the roadside habitat gradient but were still present at 9 to 12 km from the town. Introduced perennials exhibited a similar pattern of distribution (Fig. 2). Perennial forbs and grasses also declined across the habitat gradient but were less abundant than annuals along upland prairie roadsides.

In contrast, abundance of native perennial forbs and grasses was lowest in the townsite and highest in the upland prairie, creating a reverse gradient (Fig. 3). While abundance of native plants in the townsite was low, 16 species persisted despite the disturbance and

Table 1. Plants groups and species identified from transects. Matfield Green study site, 1997. An * indicates a biennial species.

Exotic winter annual grasses	Exotic summer annual forbs	Exotic summer annual grasses	Exotic perennial forbs	Exotic perennial grasses
Japanese brome *Bromus japonicus*	rough pigweed *Amaranthus retroflexus*	crabgrass *Digitaria sanguinalis*	common chicory *Cichorium intybus*	smooth brome *Bromus inermis*
downy brome *Bromus tectorum*	kochia *Kochia scoparia*	barnyardgrass *Echinochloa crusgalli*	dayflower *Commelina communis*	Kentucky bluegrass *Poa pratensis*
shepherd's purse *Capsella bursa-pastoris*	white sweet clover *Melilotus alba**	stinkgrass *Eragrostis cilianensis*	field bindweed *Convolvulus arvensis*	johnsongrass *Sorghum Á*
poison hemlock *Conium maculatum*	yellow sweet clover *Melilotus officinale**		common St. John's wort *Hypericum perforatum*	
tansy mustard *Descurania pinnata*	spiny sow thistle *Sonchus asper*		common plantain *Plantago major*	
bushy wallflower *Erysimum repandum*	hedge parsley *Torilis arvensis*		curly dock *Rumex crispus*	
dames's rocket *Hesperis matronalis**	common mullein *Verbascum thapsus**		common dandelion *Taraxacum officinale*	
henbit *Lamium amplexicaule*			white clover *Trifolium repens*	
peppergrass *Lepidium densiflorum*				
corn gromwell *Lithospernum arvense*				
black medic *Medicago lupulina*				
chickweed *Stellaria media*				
penny cress *Thlaspi arvense*				

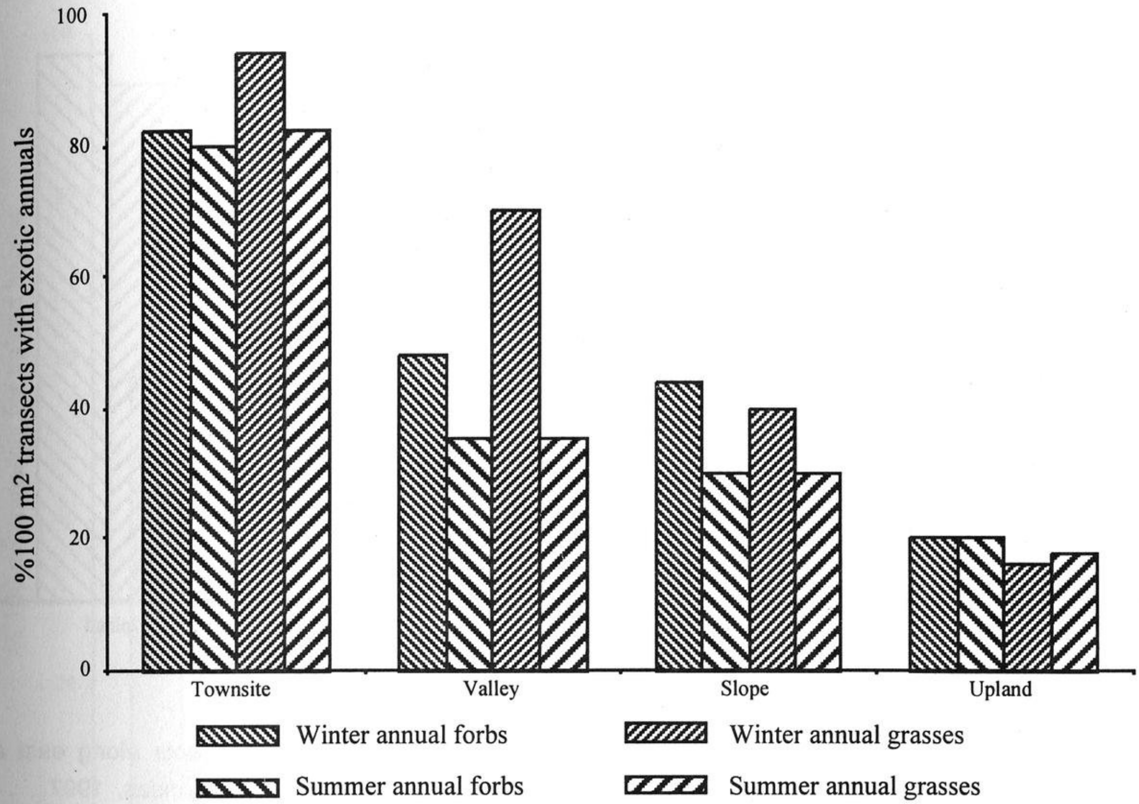

Fig. 1. Frequency of nonindigenous annuals in 100 m^2 segments of continuous transects along east and west roadside gradients form townsite to upland prairie habitat. Chase County, Kansas, 1997.

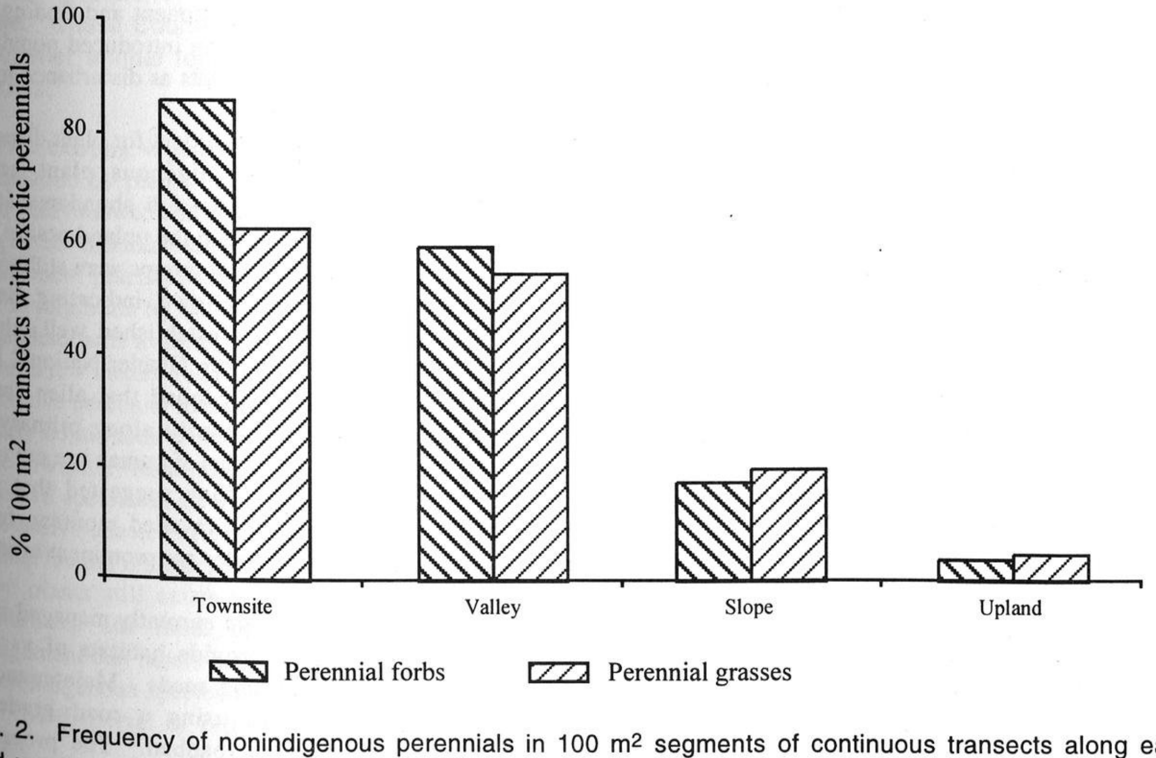

Fig. 2. Frequency of nonindigenous perennials in 100 m^2 segments of continuous transects along east and west roadside gradients from townsite to upland prairie habitat. Chase County, Kansas, 1997.

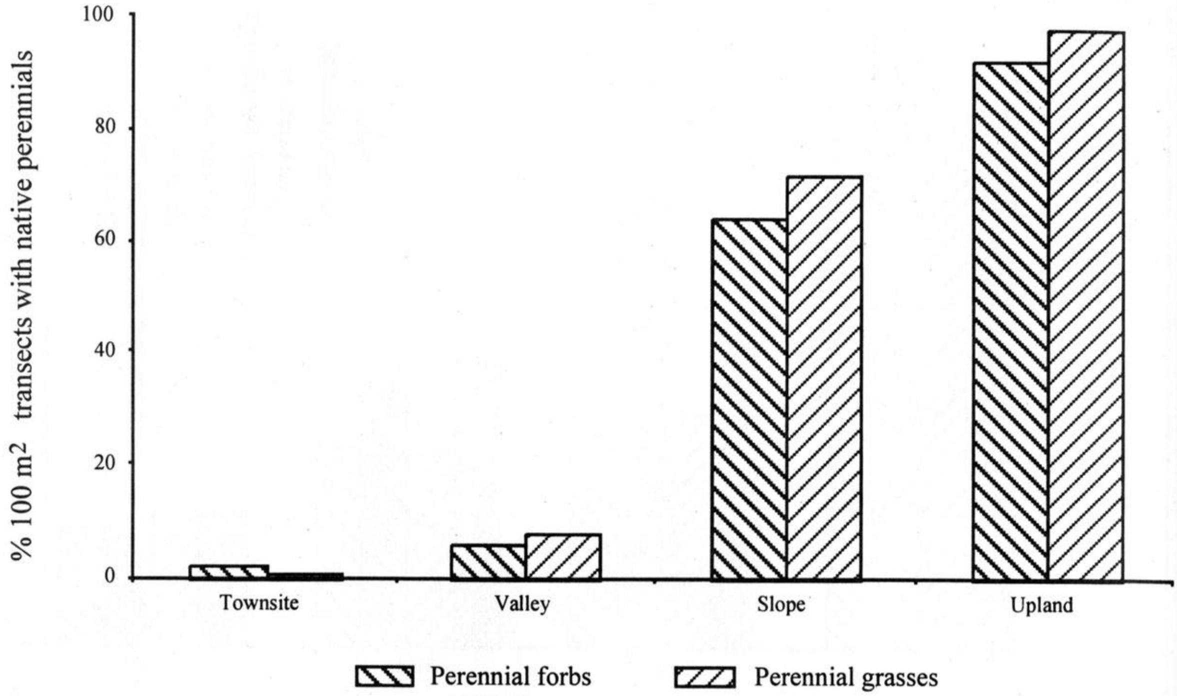

Fig. 3. Frequency of native perennials in 100 m^2 segments of continuous transects along east and west roadside gradients from townsite to upland prairie habitat. Chase County, Kansas, 1997.

the high percentage of introduced species that were present. The abundance of introduced species of all life-history classes was higher on the truck trails leading out into the upland prairie than on the paired transect through the prairie (Fig. 4). Winter annual forbs and grasses were more abundant on the trail than summer annuals or perennials, but all were making inroads into the prairie via the trails.

DISCUSSION

High abundance of both annuals and perennials suggests that townsite plants are a source population for nonindigenous species spreading into the prairie. Disturbed sites are attractive to colonizing species and the species that populate early stages of a succession are often those with good colonizing ability (Tilman 1990). Good colonizers may have some of the life history traits that Baker (1974) attributed to ideal weeds. Traits such as rapid growth, high seed production, and vegetative reproduction (as well as sexual reproduction) make these species especially well suited to townsite habitats. Although not all introduced species have these characteristics (Perrins et al. 1992), most have wide environmental tolerance and resistance to further disturbance that enable them to persist. Human influence has substantially altered habitats and created an environment where the seeds of nonindigenous colonizers may find a safe site, grow, and reproduce (*sensu* Harper 1977).

Good colonizers are also good dispersers and may be predisposed to have dispersive properties (Gadgil 1971). Good dispersal ability gives seeds the option of leaving a crowded environment and finding new habitat. Once established, an introduced population may expand into other habitats as disturbance makes new sites available.

Roadways are ideal corridors for plant dispersal. Abundance in the nonindigenous plant groups declined in a gradient from high abundance in the townsite to low abundance in the upland prairie. All of these nonindigenous plant groups were still present 9 to 12 km away from the town, indicating that the species in the groups are established well into the upland prairie. In a study in Glacier National Park, Tyser and Worley (1992) found that alien species richness declined continuously along primary and secondary roads from centers of human use out to the most distant transect. They suggested that alien species have successfully invaded montane fescue grasslands and that roadsides are prominent agents of dispersal.

Roadsides, as they are currently managed in the Matfield Green area, provide habitats of variable disturbance for dispersing seeds. Maintenance of county roads involves using a road grader to periodically scrape the roadbed. The procedure

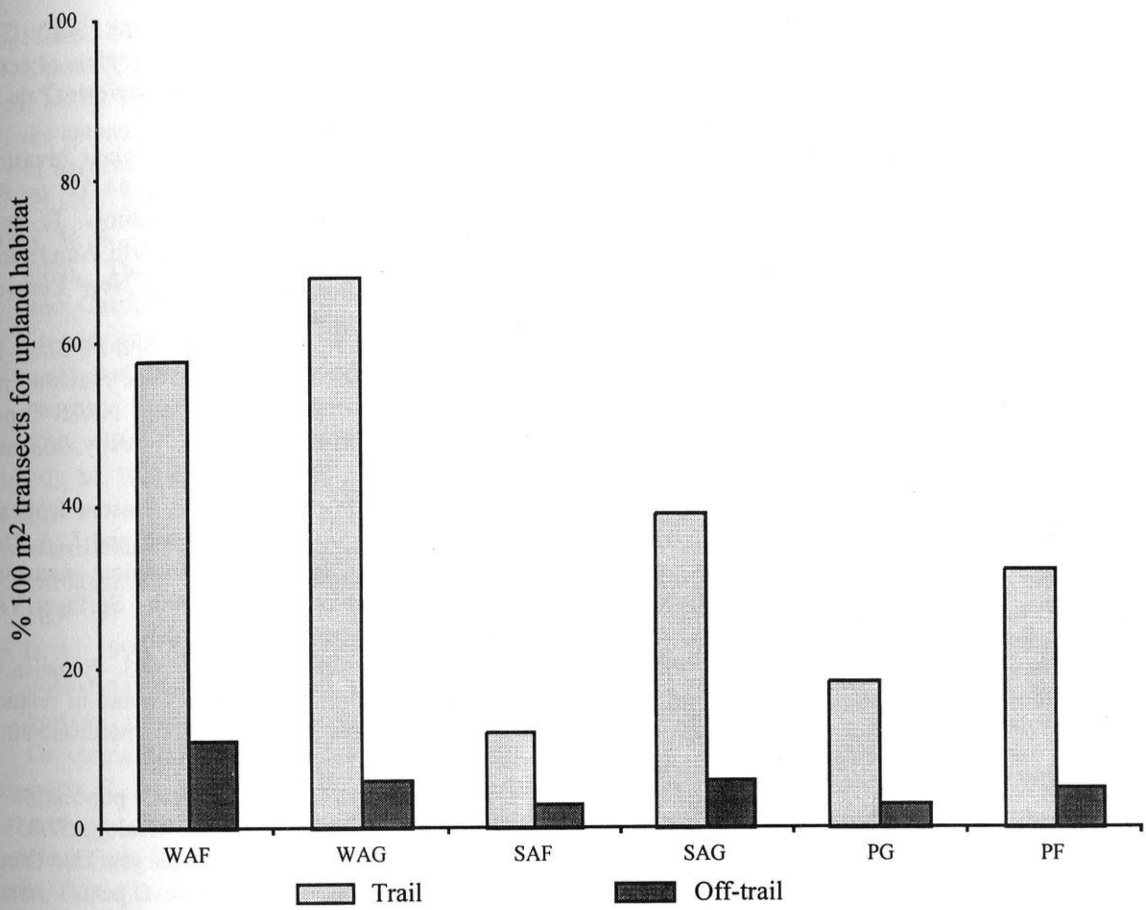

Fig. 4. Frequency of nonindigenous plant groups along trails vs. parallel off-trail sites in upland prairie. Chase County, Kansas, 1997. WAF = Winter annual forbs, WAG = Winter annual grasses, SAF = Summer annual forbs, SAG = Summer annual grasses, PF = Perennial forbs, and PG = Perennial grasses.

removes existing vegetation and opens new sites to colonization by plants. In contrast, these roads are infrequently mowed and only selectively sprayed when designated noxious weeds are observed. Road management practices create an environment that is open to migration by nonindigenous species. Newly opened habitat is available but habitat for established species a few meters away is relatively undisturbed.

Native perennial forbs and grasses declined along a nearly continuous gradient from the upland prairie to the townsite. Roadsides appeared to offer refugia for native species in all four habitats. The presence of 16 native species at isolated locations within the townsite habitat indicates that a small reserve of these native plants still exists and could provide source populations for local restorations. Roadside management that favors native species at the expense of nonindigenous species might then be expected to slow the dispersal of introduced species in to the prairie.

Nonindigenous species from all 4 life-history groups were present on the truck trails in the upland prairie, but did not yet extend deeply in the prairie. Predicting which of these species might be potentially invasive is not possible. However, Williamson and Fitter (1996) have proposed the "tens rule" to describe the invasive ability of introduced plants. They found that, for pasture plants in Australia and for pines in Great Britain, 10% of introduced species became naturalized and 10% of those became invasive pests.

Although these values are low in comparison to the total number of introduces species, there is always the potential for a species to become highly invasive or disruptive to the native plant community. Krebs (1994) has argued that displacement of species in a diverse native plant community by an invading species can alter an entire ecosystem. Plant invaders that gain earlier access to resources (or use them more efficiently than natives) can alter productivity, decomposition, moisture regimes, nutrient cycles, soil fertility, and erosion factors (Vitousek 1886). Invaders can modify plant communities by increasing fire frequency (Vitousek 1986), and they can also alter habitats for wildlife (Trammell and Butler 1995), or create new habitat for a different suite of species (Vitousek 1986).

Invasive species can establish at low abundance for several decades, then accelerate population growth and spread rapidly (Moody and Mack 1988). There is often a time-lag between an introduced species arrival and its subsequent spread. The Brazilian pepper tree (*Schinus terebinthifolius*), a ubiquitous exotic in southern Florida, was present for 50 years before it became a problem species (Ewel 1986). Approximately 80 years was required for Japanese honeysuckle (*Lonicera japonica*) to become an even more widespread pest (Hardt 1986). Once a species begins to spread it can do so rapidly (Forcella and Harvey 1983, Baker 1986). In portions of the Kansas Flint Hills, I have seen sericea lespedeza (*Lespedeza cuneata* (Dumont) G. Don), after years of low population growth, undergo a rapid range expansion that may eventually threaten the livestock industry in the region.

Most invasive plant species cannot invade a stable plant community without some disturbance to the community structure. Human activities (such as annual burning, double-stocking of livestock, and other anthropogenic disturbances, as well as periodic drought) provide the opportunity for expanding populations of introduced species to enter the prairie. Overgrazing of native perennial bunch grasses in western North America facilitated the invasion of downy brome (*Bromus tectorum* L.) that has replaced the native vegetation (Mack 1981). Currently, California grasslands are entirely composed of introduced species (Jackson 1985). Introduced species have entered the upland prairie at Matfield Green via roadway corridors. If the prairie is susceptible to invasion and potentially invasive species are present, then further invasion by introduced species depends on pattern of disturbance and the competitive interactions of the plants.

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CHANGING THE PUBLIC'S PERCEPTION OF TREES AND PRAIRIES

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Abstract: Most of today's society tends to view trees as a synonym for nature, or at least as necessary components of any natural area. Tree planting is advocated as one of the best ways to help save the earth by many environmental and conservation organizations, even in prairie states. These views often clash with the goals of prairie conservationists who are working to remove invasive trees from an endangered ecosystem. Recent events have reinforced the seriousness of the tree hugger mentality as a threat to prairie conservation efforts. We need to find ways to turn the public's devotion to trees and tree planting into a better understanding of the beauty and importance of prairie. The first step is to gain a thorough understanding of the underlying reasons for the attraction of humans to trees, and their relative indifference to prairies. Some of the most important of these include history, the perceived lack of diversity in prairies, relative accessibility, and successful advertising by tree advocates. We then need to attack the problem through education and by improving public access to prairies. If we fail, the country's remaining prairies may be destroyed by its own good intentions.

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Key words: diversity, prairie conservation, tree hugger mentality, tree invasion.

Prairie conservation has been gaining momentum in much of the country. However, the enthusiasm for prairies lags far behind the long-held and strong attraction of people for trees. Unfortunately, prairies and trees are rarely complementary. At this point trees have won out in situations where people have had to choose between them and prairie. To ensure the continued and long-term success of prairie conservation and restoration work in this country, we need to address and transform the public's sometimes irrational love of trees and tree planting into a more realistic view of trees, prairies, and their respective places in natural systems.

In this paper, I will look at the current feelings of the public toward trees and prairies, as well as some of the underlying reasons for those feelings. I will point out several negative impacts of trees and the public's love for them on prairies. Then, I will address the major misperceptions held by the public about trees and prairies and discuss how these can be corrected. Finally, I will outline some of the most important actions that need to be taken to begin the long road towards transforming the public from tree huggers to prairie nuts.

BACKGROUND

Americans love trees. We hug them, decorate them at holidays, and chain ourselves to them to prevent their destruction. We plant them for shade, for windbreaks, for their fruit, to memorialize loved ones and important events, and for the wildlife they support. But mostly, we just like to have them around. Many trees are nurtured and cared for as if they are members of our families. Every child in every school in the nation learns about the importance of trees to our culture, our industry, and our lives.

In contrast to their love of trees, Americans are generally oblivious to prairies. Prairies are romanticized as the historic domain of cowboys, Indians, and buffalo, but are basically forgotten in the present. In fact, the disappearance of the romanticized version of Indians, buffalo, and to some extent cowboys, is probably one of the biggest reasons that prairies have such a public relations problem today. There really is not anything left about most of today's prairies that is attractive to the romantic human mind. The most striking and attractive aspect of historic prairies was their seemingly infinite size that seemed to envelope the viewer. Because most of these vast prairie landscapes are gone (along with the big furry animals that roamed them), there is little left to draw people to the small remaining prairies to appreciate the other major attractive component of prairie, the colorful diversity of flowers, bugs, and birds found there.

Trees are easy to understand and appreciate. They are big, they live a long time, and each is individually unique. These are the same things that humans tend to admire and relate to in other humans. Trees also harbor a variety of large, attractive mammals and birds. In contrast, prairies are made up of a confusing array of small plants that all look the same from a distance. Most tracts of grassland are managed for forage production and have relatively few wildflowers to provide obvious aesthetic beauty. The big showy animals are mainly gone, leaving small animals that are hard to see, and to most people just look like little brown birds and bugs

NEGATIVE IMPACTS OF THE TREE PLANTING LEGACY

The end result of the contrasting public perceptions towards trees and prairies is that while prairies have nearly disappeared throughout most of their range, trees are increasing in number in those same areas. When European Americans first began crossing the Mississippi and Missouri Rivers and settling in the great North American prairies, they began planting trees almost immediately. They were encouraged by a need for wood and protection from harsh weather, by government incentive programs, and by advocates who proclaimed that the benefits of trees included improved monetary income, increased patriotism, moderation of temperatures, draining swampy land, and increased rainfall.

Today the tree planting continues. While we have dropped most (but not all) of the climate changing benefits from the list of the benefits, we have added equally grand values of tree planting, including helping wildlife and saving the earth. In addition to tree planting, the number of trees throughout the prairie region is increasing because trees are often allowed to propagate with little or no check on their population growth. Weedy species of trees such as eastern redcedar (*Juniperus virginiana*) and Siberian elm (*Ulmus pumila*) are just two of many tree species whose populations are growing at an alarming rate. As an example, recent information from the Nebraska Forest Service showed a 30% increase in the state's forested land from 1983 to 1994. That included a 50% increase in eastern Nebraska, where tallgrass prairie has declined to about 1% of its historic range. That increase does not include the many areas that now have trees as a component of the landscape. It only includes areas that are characterized as forests. In addition, timberland area with redcedars as the dominant species increased by 67% during the same period.

Ironically, many of the areas that have been hardest hit by woody plant encroachment are public and private lands that are being managed for wildlife species. Because traditional game management techniques include the maximization of edge habitat, trees are seen as positive additions to wildlife preserves, both for game species and numerous species of attractive birds and mammals. Unfortunately, once trees are introduced to these natural areas, they are usually allowed to spread until the entire natural area is wooded. Once trees become established on a site, they are unlikely to be removed. Because of public sentiments towards trees, and because of widely publicized anti-logging efforts in forested parts of the country, cutting trees is generally avoided by governmental agencies, and is not seen as positive by most private landowners.

Even if encroaching trees do not take over an entire natural area, even partial encroachment of trees into a prairie can drastically change the suitability of that prairie has habitat for many grassland species, particularly grassland birds. Some of the grassland bird species experiencing the steepest population declines across the continent are those that avoid nesting near trees and in small patches of prairie that do not provide a core area free from the negative effects of patch edges.

MISPERCEPTIONS ABOUT TREES AND PRAIRIES

While encroachment of trees is a serious threat to the remaining fragmented prairies in the Midwest, the general public's current perceptions towards trees constitute an even more serious threat to the prairie conservation movement as a whole. There are several misperceptions about trees that are generally held by the public that must be corrected if prairie conservation is going to succeed.

The first is the perception that trees in the prairie regions are less abundant now than they were historically. While some native forests have been diminished through clearing for agriculture or development, this has been made up for many times by the increase of trees in other parts of the landscape. The public needs to be educated about the difference between the maintenance and restoration of native forests, which is certainly important, and the encroachment of trees (both native or non-native) into areas where they do not belong.

A second misperception is the very generalized concept that trees are positive for wildlife and/or diversity. While forests undoubtedly have more species of recognizable wildlife than prairies do, most of those found in small patches of woodland are generalist species such as American robins (*Turdus migratorius*), blue jays (*Cyanocitta cristata*), deer (*Odocoileus* spp.), and raccoons (*Procyon lotor*) that have become excellently adapted to today's fragmented landscape and are now superabundant. In contrast, most of the species in need of conservation attention are adapted to open wetlands and prairies. Instead of adding to the diversity of a landscape, the addition of trees often excludes many rare prairie and open wetland species and provides habitat for already common edge species, thus lowering the diversity of the landscape. We need to get away from the idea of managing small parcels of land for the maximum number of species within that particular parcel, and work to see how each parcel of land can be managed to contribute to the overall biodiversity of the landscape it belongs to.

A third and related misperception of the public that needs to be altered is the idea that trees are necessary in order to have a quality natural area. This concept is fueled by the fact that the majority of publicly accessible hunting and recreation areas are heavily wooded. When people go out to have fun in nature, they go to these wooded areas and develop a mental connection between areas with trees and good natural areas. We need publicize publicly accessible prairies and advertise some of the more attractive features of those areas such as the diversity of butterflies, flowers, and birds that can be found there. Only then will people start to incorporate prairies into their conceptions about nature.

The fourth misperception is the overly broad idea that planting trees is somehow automatically good for the earth in general. This seems to have become an almost mystical quality attached to trees. While trees have many useful purposes, there is little data that show tress have any magical earth-saving properties. Yet environmental organizations put out lists of what one can do to help the earth, and planting trees is usually a prominent activity (along with picking up litter and recycling).

In general, a big goal of prairie conservationists should be to get the public to see trees simply as big plants. As such, trees can be positive in areas where they are supposed to be: forests, windbreaks, urban plantings, etc. But like other plants, they can be weeds where they do not belong, particularly in prairies. We need to teach the public and other conservation organizations and agencies about both the negative and positive impacts of trees so they can make educated decisions about where they should and should not be.

ACTIONS

To change the public's attitudes about trees and prairies, we need to simultaneously attack the aforementioned misperceptions about trees, and vigorously advertise the positive aspects and conservation needs of prairies. The first obvious step in changing general opinion is to continue efforts to improve public education about trees and prairies. Schools, nature centers, university extension educators, and other similar groups and individuals need to be provided with materials and information that realistically portray the role of trees in today's landscape.

They also need colorful photos, interesting facts, and eye-popping statistics about prairies and their plight (similar to those now available for rain forests). Instead of the intricate complexity of prairies acting as a stumbling block to the public's understanding of them, that complexity should be promoted as one of their biggest assets. Land managers, ecologists, and naturalists should take every possible opportunity (during hikes, presentations, etc.) to expose the public to prairie organisms and ecological systems, and to stress the importance of prairies to biodiversity. The more intimate people become with prairie organisms and ecosystems, the more likely they are to see the importance of protecting them. Building a constituency of prairie enthusiasts is a slow process, but is probably the only way to ensure the long-term survival of prairies.

Along with generally educating the public about prairies, there is a great need for improved public access to high-quality prairies. Many organizations that manage or restore prairies have developed a very protective attitude toward their land. While it is obviously important to prevent excessive disturbance to fragile communities, there are many ways to allow public access to many prairies (or at least parts of them) and still adequately protect them. Some of these include regular, advertised, guided tours, self-guided nature trails, or even interpretative signage that describes a prairie without allowing actual access into the area itself. Most prairies are rugged enough to stand a fair amount of foot traffic without undue harm. The biggest problem may be controlling litter, vandalism, and other problems that can sometimes accompany public access areas.

A third thing that needs to happen is to increase the exposure of and public involvement in prairie restoration work. If we could transfer even some of the time, money, and energy now spent on planting trees into clearing them from prairies, collecting and planting seeds, and even chopping thistles, we could make huge strides in restoration work. The biggest advantage, rather than increased acres planted, might be an increased feeling of connection with and ownership of prairies by the public: an important step in their long-term protection. Besides simply inviting lots of people to help with prairie work, we need to do a better job of getting media coverage for our work. Public work days should get coverage by newspapers and television, and should provide a telephone number to call for more information or to find out how to help. Also, big restoration projects, particularly those that are clearing trees in the process, need to be publicized as much as possible. Many of us have been reluctant to do this in the past for fear of public outcry, but the first step in getting public support for prairie conservation, and tree clearing in particular, is to initiate a public dialog. If we continue to clear trees surreptitiously, we risk more serious problems, as exemplified by the recent situation in Chicago where a moratorium was placed on any prairie restoration activities within the city after the press and public rose up against what they saw as a plot to kill trees behind the public's back (see recent issues of Restoration and Management Notes for articles and discussion). Instead of getting negative public exposure all at once, it is better for us to work out in the open and educate the public as we go.

Besides working with the broad public, we also need to educate landowners about the value of prairies and the potential negative aspects of woody plant encroachment. A good first step in this direction would be to get some of the more aggressive native and non-native tree species recognized as rangeland weeds by the agricultural community. Working with the press, extension educators, and agencies such as the Natural Resource Conservation Service and the Farm Services Agency in this regard is crucial. If we can get species such as eastern redcedar, Siberian elm, buckthorn (*Rhamnus* spp.), and Russian olive (*Elaeagnus augustifolia*) recognized as official weed species in areas where they are a problem, it will encourage landowners to be more diligent about removing them from their properties. More importantly, landowners who do not control those species will be influenced by their neighbors to do so, as they currently do with musk thistles and similar weeds.

Once landowners recognize encroachment by trees as a problem, as some do now, we need to ensure that there is both informational and financial support available for those landowners to clear and control encroaching trees. Private and government organizations should be urged to provide cost-sharing support for clearing operations, as they do now for tree planting. Additionally, there is great potential for partnerships between private landowners and conservation groups and local logging companies. The Nature Conservancy here in Nebraska provides one example of how this can work. The Conservancy is working with a local logging company to clear nearly 300 acres of dense eastern redcedar that has encroached into a recently acquired prairie. The logging company agreed to clear all the trees on the site for the money they could make by selling the marketable logs for wood shavings and fence posts. Neither partner paid any money to each other, but both are getting what they want from the deal. The Conservancy is also publicizing the project in every way possible to increase awareness of the problem and a possible solution, as well as to help the logging company find other jobs after the completion of the current project. Prairie conservationists should be encouraging this kind of partnership by helping to link up loggers with willing landowners and by working with logging companies themselves.

CONCLUSION

To ensure the survival of prairies and the prairie conservation movement itself, we must have public support for our efforts. To get that support we need to change the strong current perception that nature and trees are inseparable and get people to recognize and appreciate the more subtle attractions of prairie. This will include education both about the potential negative impacts of trees and about the many positive aspects of prairie. Besides just improving education programs, we also need to find more and better ways of directly involving local communities in prairie conservation projects around their area to forge an emotional link between people and prairies. This may involve some conservationists changing their attitudes about allowing public access to prairies and about media coverage of their work. Transforming trees from magical creatures to humble plants will not be an easy or short term project, but is a very necessary goal if prairie conservation is to succeed.

LETTERS FROM THE LAWNS OF GOD

DYCIE J. MADSON, Godfrey, Illinois, USA

Abstract: These are fictional letters from the women of a wagon train on the trip across Illinois and Iowa. They are interspersed with excerpts from real letters and Botanical references with medicinal uses of the plants. The experiences that my husband, John Madson, and I had while working on *Where the Sky Began* and camping on most of the prairies in tallgrass country are combined with many inherited tales and letters that our family possessed.

PROCEEDINGS OF THE NORTH AMERICAN PRAIRIE CONFERENCE 16:28-34

Key words: Great Migration, Illinois, Iowa, wagon train.

Friends and colleagues, I am not a botanist, zoologist, hunter or woodsman; however, that is the vicarious life I have lived. My husband, John, and I covered many of the prairies of the Midwest and West. We are both children raised in the dust of the 1930's weather, the Great Depression, and floods. We have floated the Mississippi River, the Missouri River, and climbed the Loess Hills in Iowa many times. We were fortunate in our ancestors who left comfort back east to follow the "Great Migration," and we inherited marvelous letters and accounts of that time.

I have begun a survey of that migration by examining letters sent home. I first thought I would write a little uplifting, "small" volume that touched on the ladies' lives and the herbs they used with botanical illustrations; but as things like that go, it has gotten out of hand.

Dean Roosa, Sy Runkel and Don and Luella Resse of Turin Iowa are my most frequent sources of information and inspiration. But Harriet Choice, an old friend from Universal Press Syndicate, has cracked the whip and insisted that I get **to** the prairie, break the prairie, ruin the prairie and then restore it. I am not sure I am capable, or that it is even possible. Perhaps by the next North American Prairie Conference that work will be finished. As of now, here are a few of the letters sent home from the long walk over the lawns of God in the 1870's.

My darling daughter suggested interspersing these fictional letters with real journal entries by Mary Jane Bonnell-Cooper given to us by a family member.

Mary Jane's journal begins like this....

Winterset camped 2 miles this side

got our stock in a pasture

paid 2.40 for it

made 24 mile this morning

it was rainy and we didn't start till 10 but it has been a splendid day

is a nice evening

we have come 18 mile over much open prairie

crossed middle river on a covered bridge

stream not a large as big creek

camped here on a small stream in the edge of the timber

movers all around us

some of them have been to see us

one young man brought his fiddle and played

made me think of Joe Rice

and now it is late and the rest are in bed the boys seem to enjoy them selves first rate

May 30th

another nice day and we have drove 25 mile and had a bad road over a hill and into a slough

we are now in Adams Co.

we camped last night on Grand river half as large as big creek

it has been open prerie all day no fences--crops all out,

one man was agoing to shoot our horses

he was Irish

we had quite a time and some body like to got whipped.

we are camped tonight on a little creek on the open prairie and I wish it was morning and I dread tomorrow

we are 13 miles from Quinay

March

Dearest Mother,

The geese are up and flying and I guess we are, too.

Early yesterday morning we left on the great adventure. When I wrote last month about the fever we all had to go west, I never thought that we might really go. Thomas is convinced that the future is WEST. We have been packing and unpacking for days trying to fit everything we will need into the wagon. It is not the big Conestoga, just our old hay wagon fitted with a canvas top.

Thomas has been so clever packing the wagon with layers; the things we need for travel on the top and the things we will need later underneath. The plow we have just bought is at the bottom, while the wooden wash tubs that we will need for many things are in the middle. The soap kettle, the soup kettle, the Dutch oven and the lard bucket are nested with utensils and tin ware inside, I must keep my roses alive and our seeds of all kinds are packed in sacks of all sizes that I have sewn, the bulbs are wrapped in straw and I have them arranged them along the sides of the wagon on a narrow shelf that Thomas has built. Finally, the bedding goes on top and we are all organized.

Cholie says we will be sorry that we are going so far-- that the rivers will kill us and the Indians will kill us. Gloomy Martin seems to believe him, but I wish Martin wouldn't come with us. It will be hard enough to travel with cheerful companions.

The new territory was designated for the Illini and Iowa tribes, but their chiefs have marked new agreements and now the in— between places are open.

Every time we see a report from the west we know that the blank places are filling up with our people longing to see beyond the horizon. I am torn as a Christian about the way we treat our Native Americans—even though no one else seems to be. The government wages war on the tribes, but many of us would like to learn from them and persuade them to learn from us. They are so different in their ways. They don't seem to have individual land ownership as we understand it.

The weather has broken and today is a shining cut-glass day, with snow left in the shadows and Pasque flowers blooming. With much faith in tomorrow I picked one to press in my bible—a beginning and a farewell. I never thought of leaving Louisville, but we have been here a long time and the whole continent is calling us. It whispers in our ear, come, come west!

Love,
Stella

May 31st

we have made a short days drive today

we found very bad roads sloughy and about 10 it began to rain and we have put up for it is slippery and very hilly now

our stock is in a honest mans yard and our wagon , in a lane

if they will let us we will sleep in their house and they will say we have come only 7 miles today

June 1st

we came on this morning after a good night rest in a good bed

passed through Quincy

it is a dead old place for the county seat

the RR passed within 5 mile of it and killed it

they say the county seat will go to Corning-

we crossed about 4 Nodawa rivers south north middle and west and here we are camped on the west Nodawa and as many as 25 movers wagons in sight

we have come 25 mile today

it looks like rain.

June 10th

have traveled over prairie

not much settled

no fences

some live in houses and some in dugouts

Lincoln is a pretty place but still i looks wild without a bit of fence-

passed over a beautiful prairie

came through Crete tonight

crossed the big blue

are camped on a small stream

saw Loverly this morning at McClinties

he said they should overtake us before we got to Crete but he was not there

was a severe tornado passed through here about 2 weeks ago

killed some.

Dear Mother,

The great forest exhales a mist of leaf mold and scents. Last night our wood was damp and the fires burned fitfully through the campground, slowly drifting threads of smoke wavered up a hundred feet into the massive branches of oak, tulip and sycamores trees. Ancient giants in an ancient flood plain stand sentinel to all we have left behind—comfort, safety friends, and home.

This morning we ate hurriedly, scoured the iron spider in the creek and hitched the mules to the wagon. It is soft underfoot and our shoes are forever wet. The detritus of moss and ferns have accumulated to make a carpeted park—land, it is always dim, church-like, even on the brightest day... The children see shadows in the forest— Indians, bears, wolves and such. Mostly, it is just their childish understanding of things the grownups have discussed and the children listen, unaware.

We find walking much easier than riding, only the small children or those who do not feel well ride. The trail is so very rough. I can not finish this epistle for the wagons jolt and sway too much, I will try to write more, tomorrow.

It is evening and I must hurry to write before sundown. Even when we have crossed the Wabash River, I know it will still be time and time and time before we arrive at our destination The Seals family went out last year and sent back reports of the great fertility in the country of Iowa. When it was designated "Indians Only" it was very dangerous.

They say that there are still renegade bands of Indians roaming the prairie, but most of them have signed treaties and reservations have been agreed upon. It seems so cruel to me that they should give up land that once was theirs. But often the chieftains agree to sell the land or make treaties. They may not understand that the land will be broken and farmed. How could they know when they have always used the land as a group and as a hunting ground? Stella and I talk of this endlessly, but Naomi makes much fun of us and Cal gets angry. He turns purple at the mention of Indians as people. He calls them dirty savages. Pshan Shaw, an Indian woman traveling with us, is silent and continues weaving her beadwork moccasins and possible bags. I am embarrassed.

There are more meadow-like openings in the forest now and as we wind through the Goliaths of the flood plain. We remark on our gratitude that we will not have to clear our new land of trees—only break it! The plow that we have bought is new and highly praised. We all hope that it lives up to its broad sheet.. Say a prayer for us.

Love,
Martha

June 12th

we have layed over today on account of rain

we had a dreadful storm last night

blew awful

the road was to slippery to go on today but it cleared off and we have some work and the young folks put up a swing-

passed over prairie

mostly good roads

saw one gray fox and two antelopes

are with 2 mile of Meridian-

we have traveled over open prairie since we left Meridian without a drop of water or a single tree

we could see houses and trees way off over the prairie

it rained a little last night but the roads are good in Nebraska if there's nothing else good

we picked some prickly pears today that had large yellow flowers on

so beautiful if I could only send one to Lizzy

just as I pulled it up I know she would have admired it much

it has rained this afternoon and it needed it

it looks better than it did but there is no homestead short of Franklin co. where Loverly has gone

Mrs. L. is a nice woman but she has a time with her 3 small children.

now who shall we see next that know

we met Washburn near Lincoln going for his family and day before yesterday we met Luchbow and them

June 19th

we have traveled only 15 mile

are camping by the Republican in Rep. Co.

Dear Lucy,

The air is watermelon sweet this morning, crisp and with a hint of sun to come be noon. The children actually helped pack up the breakfast things and were in their places in jig time. Please tell mother we are well. Tonight they said that we will see the Grand Prairie soon!

The men have sent young Ian and Nathaniel out to find a campground. I wonder what a country without trees looks like? There is so much controversy about whether the soil is good or poor. I know I sound jumbled, but Cal has been so controversial and is agitating for us to go to gold country. Lucy I don't want to go prospecting I want a home. Sometimes I wake in the middle of the night frantic that we are out here suspended and drifting with no place left to us. Why is Cal so cross grained?

In the middle of the afternoon we stopped to eat. Out ahead the corridors of trees show black against a great light. We are dazzled, curious, apprehensive; hurrying toward a abyss of sun. We have been from sun to shade opening into cathedral avenues so many times I have lost count. Shortly, we may see it—the prairie. the children are so excited that they can hardly eat. So are we.

We don't know what will grow out there. We don't know if our seeds are the right ones—or what we can use to build our houses. The Seals wrote that they have built a house of sod—I don't know what that will be like!

DEAREST Lucy, I sound such a coward, but I really feel strong, able to do anything even with the little sleep that we have had at night. The winds moan through the forest and the uncertainty, the illnesses of the vast flood plain have been a trial. But we persevere against this gloomy magnificence.

Baby Flora tries to pull up on the wagon gate. She has all the others in an uproar over her antics to get out and join us walking.

It has taken longer than we expected. The setting sun makes sunstars through the branches of the trees. Soon it will be too dark to see, so again we must wait to reach the edge. A few more hours to camp and then, tomorrow—GRASSLAND.

Love,
Stella

not much timber and am real homesick

criedd most all day

this is the last night we camp with Asa

he gets home tomorrow

we either cross over into Jewell county or go back to Turkey Creek

have come 23 mile and only seen some dugouts from the road

it is very warm and looks like rain

we came through a real prairie dog village today one little chap stuck his padded nose up and barked

we saw many buffalo bones but no buffalo yet

13th

we drove 35 mile and the last part in the rain

slept in our wagons for the first time and had a hard night.

plenty of room in a house and barn near but they ar too mean to let us in

rained all night

4th

drove 7 mile for it rained all the forenoon

we are at a hotel in Nebraska City and it has cleared off real nice but I am so tired and most sick

15th

paid a 5 dollar bill at the hotel and crossed the Missouri

had 8 mile of mudy bottom to drag through Sidny county seat of fremont -

5 mile from the river camped on the Nishnabotna-

Dear Grandmother,

We are so fortunate to have Adele to teach us and to read to us at night. The children love her and she has books that we can use for school. We gather at sundown, light the lamp and read aloud from Adele's books. The little ones twitch and squirm with Flora going unsteadily from one to another making faces and babbling. The older youngsters make calves eyes at each other while the boys try to teeter along the wagon tongues showing off.

Tonight Adele read a poem by Shakespeare about Spring. Most of us thought that Shakespeare was old and boring...

> **Now daisies pied, and violets blue,**
> **And lady-smocks all silver white,**
> **And cuckoo-buds of yellow hue,**
> **Do paint the meadows with delight:**
> **The cuckoo now on every tree,**
> **sings cuckoo! cuckoo!**

Even though our daisies will be Pussy Toes and our Lady Smocks will be Lady Tresses, our cuckoos are the same, with red eye patches and guttural voices. Our young people are a despair and a delight, filled with wild exuberance or sunk in despair! Spring has made them all a little cuckoo!!

Love,
Serina

My dearest Lucy,

I miss you so very much even though I know you could not come, I know you want to hear how the travel fares. Ramrod Cal sits on that big black stallion and treats anyone who asks to ride such a horse with viscious contempt. No one touches his shining hide. Oh well — we must endure...

Yesterday was one long misery with rain and lightening battering us on the trail. The evening meal was cold and comfortless and progressed to a fearful night with cattle stamping and lowing. Our ladies are eternally tired and out of sorts, but today we will rest and try to recover our good senses. The morning has cleared and we have sent the children to pick flowers. Perhaps they will find a few trilliums blooming, we will decorate the table and more-- They say that an infusion of the root will ease births and assuage internal bleeding, or stop external bleeding when made into a poultice. The Indian woman who is traveling with the Williamses says that trillium is a good eye medicine, as well.

Flora has pulled up and is unsteadily walking, bless her heart she has little opportunity to do so with the five o'clock call and ten hours of moving. She is so sunny and sweet that even the bigger boys try to please her, her name describes her. Philomena and I are worried about her cough and Pshan Shaw is plying Adele with remedies for her.

Love,
Stella

Dear Grandmother,

We were so glad to get your letters in Springfield! Please remember me to Alice when you see her, but if that Theodore should accost you , pretend he isn't there. He sent me the awfullest poem. I suppose it's meant to be funny and all the other young ladies laughed, but it was so uncouth. Please tell me what you think, Grandmother?

THE STORY OF THE POLLY WOG

Within a dell
Where cowslips dwell,
A love-loin frog
Sat on a log.

With Sighing croak
His love he spoke
For Polly Wog
A lady frog.

She swore that she
Would faithful be,
And never wed
None else, she said.

And as she spoke,
A fatal stroke
kerflopped her frog
From of f that log.

With piercing shriek
The maiden meek
Leaped from her log
Into the bog.

His murderer bore
To distant shore
Her lover dead
With riven head;

And skinning him
He served each limb,
All broiled on toast,
To hungry host.
But in that bog,
Upon a log,
Another frog
Loved Polly Wog.

And such is life-
Come death, come strife,-
Our Polly Wog
Loves t'other frog.

When you see Theodore, please tell him I think he is terrible. Dear Grandmother we are all well and hope you are, too.

Love,
Georgianna

There is a poignancy in the real letters home that only hint at the resilience required of these people. We are not aware of the pressure of hunger, thirst and helplessness in the face of nature—until it is thrust upon us. We have made many mistakes, both governmental and personal, in the 4 or so generations since settlement of this part of the world: mistakes making our laws, guiding our government, and personal mistakes raising children and worrying about how much we can get. We have taught our children that they deserve everything and only have to pay for it with money.

They, our children and grandchildren, may have to learn stringency again, and I hope they will learn that frugality with the same grace as did our migrants of the 1800's. I hope they will realized that hard doesn't mean unlearned. Uncomfortable doesn't mean without beauty and music or laughter.

WILDFLOWER IMAGES IN PRAIRIE QUILTS: REAL OR ABSTRACT?

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Abstract: Looking at a "Grandmother's Flower Garden" quilt typical of the 1930s, when many of our mothers and grandmothers pieced and appliquéd their finest works, one might believe few quilters knew what a wildflower looked like. A closer look at the fibers, stitches, and blocks of twentieth century Nebraska quilts, taken during the summer of 1998, revealed that most pattern designers and quilters recognized the basic parts of prairie wildflowers, and a few shared their rare appreciation for wildflowers through their quilts. This closer look reveals a hope that as quilters can learn and share their understanding of prairie flora, scientists can learn and share a more accurate understanding of quilt culture.

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Key words: appliqué, flower garden quilt, quilt culture, quilt pattern design.

Is it wild or is it cultivated? Is it native or is it transplanted? Those questions may be as difficult to answer as whether the images in prairie quilts are real or abstract.

Quilters develop images on their products in several ways. Most people know that quilts have a front and a back and a middle (Hall and Kretsinger 1935). The back is usually plain except for designs in the fabric or any stitches which help hold the middle (often called batting) in place so the batting does not shift into clumps. Batting (also known as "bats") may be cotton, wool, polyester, occasionally paper or other fabrics, and on rare occasions there will be no batting in the middle of the quilt.

Wool was most frequently available in the Northeastern part of the U. S., while cotton would have been grown in the South. Stearns & Foster Co. produced cotton bats in the early twentieth century under the name Mountain Mist (Waldvogel 1995). Mountain Mist polyester bats were most common in the 1970s and 1980s when this author began quilting, but cotton bats are again readily available as many quilt purists choose only 100% cotton fabric, batting, and thread. I have also seen a paper-lined quilt from China, and G. Snyder's "Flower Basket Petit Point" (Snyder 1942-43) is an example of a quilt with no batting. The seams from the many small pieces served as the batting in "Flower Basket Petit Point."

The front of a quilt usually has some kind of a design in the fabric, stitches, or patches. This paper explains common methods of using or developing these images.

The first type of wildflower images discussed here develops through the designs on the fabrics. Others patterns develop through the quilting stitches which hold the 3 layers of the quilts together. These patterns are most subtle and may not appear in pictures unless the quilter uses a contrasting thread, or unless the photographer has deliberately attempted to capture minute details. The most commonly recognized quilt images develop through the quilt patterns which are pieced into or appliquéd onto the quilt top. Through a quick view of several quilts and quilt patterns, both real and figurative wildflower images appear.

FABRICS

To start, I need to define a selvage edge. Selvage edges are the original factory straight edges on a bolt of cloth where the threads have been finished. Quilters usually cut the selvage edges off because they shrink at a different rate than the rest of the fabric and may cause puckering in the design. Many fabrics include some information about the textile company or designer in their selvage edge.

A small sample of fabrics shows a variety of real and figurative, or abstract flower images. One piece of fabric has "Designs for R. E. D. TK6020-25" in the selvage edge. There is the additional information, "TRENDS from Medallions Elegant designs by Rhoda 'Piney Woods'," on the end of the bolt from which it was cut. This fabric shows a fairly high degree of realistic details. This sample features purple, blue, and gold pansies, flowers not generally known as wildflowers because of their frequent cultivation, but occasionally found in the wild. One of the realistic details includes the calyx on the back of some of the pansies (Whitson 1996).

"Folklore by Jennifer Sampou for P & B Textiles. 100% cotton.©" on the selvage is a dark blue piece of cloth with vines of mixed flowers reminiscent of early nineteenth century chintz designs and Baltimore quilt appliqué patterns. The images on this fabric are still fairly realistic, with anthers on the red lily-like flower, and a combination of ovate and lobed leaves (Farrar 1990). But one of the most common departures from reality already appears in this fabric. All of the red, blue, and gold flowers grow from the same vine which originates at the edge of the gold sunflower-like blossoms. Although the Michigan Bulb Co. (Anonymous 1995) offered a 5-in-1 apple tree (with Red Delicious, Yellow Delicious, McIntosh, Red Rome, and Granny Smith varieties grafted onto one trunk), no wildflowers include multiple grafts in their natural state.

A similar common rootstock with several types of flora appears in tan fabric with the designation "Fabrics from the Oakland Museum of California by P & B Textiles 100% Cotton 1998" in the selvage edge. Feathery blue leaves and green leaves with blue and pink, as well as green midribs typify surrealistic details on these plant images (Nelson 1979).

"Robert Kaufman Co., Inc. ©" on the selvage with "Kona Prints" on the bolt end identifies a fabric with many small flowers. The largest flowers are reminiscent of sunflowers with gold petals and black centers, but are only about 0.5-inch in diameter. They do not contain enough details to identify the specific variety of sunflower (Stubbendieck et al. 1994). Some other slightly smaller gold and green designs look more like leaves, although they could also be stylized morning glory blossoms with the lines representing the folds of the funnel-shaped flowers rather than the veins of leaves (Stubbendieck et al. 1994).

"Northcott Silk Inc.©" includes a tapestry-style design in lavender, rose, gold, and olive green tones. This fabric design is the least realistic of the sample fabrics because it mimics the stitch lines of several types of embroidery or needlepoint stitches, rather than the smooth or serrated edges of real flowers. The tapestry fabric also includes primarily cultivated flowers, rosy carnations and grayish blossom clusters which resemble hydrangeas or snowball clusters. Interestingly the background includes 2-tone gold shapes which could be wheat, an image which could be wild or cultivated. The least realistic flora are lavender daisies and 5-petaled gold flowers with lavender centers. Both English and oxeye daisies are white with yellow centers (Nelson 1979, Farrar 1990, and Whitson 1996).

Quilters today enjoy a wide variety of fabrics from which they choose their colors and designs. Quite a few fabrics were available during the heyday of quilting in Nebraska from 1890-1940. Depending on the quilter's location, she or he might not have had access to the same variety other quilters had (Crews and Naugle 1991). Grace Snyder, Nebraska's premier quilter, tells about using scraps and recycling hand-me-down dresses when her family first homesteaded near Cozad, Nebraska (Snyder and Yost 1963).

When Snyder made her show quilts, she searched through half-a-dozen states for the right color for the Indian brave's face on her "Covered Wagon States" quilt (Yost 1953).

Quilts are often identified as "show" or "best" quilts in contrast to "everyday" quilts. Best quilts usually have more patches, and more and smaller quilting stitches. Everyday quilts often include larger patches and may be tied, like comforters, rather than quilted. Their purpose was warmth or privacy, and large families used many quilts when blankets were not readily available.

Because the fabric companies choose the designs to print in their lines, few quilters have much control over fabric designs. I have been told that a few quilters design their own lines of fabric, and some quilters dye or paint their own fabrics for custom designs, but most quilters simply choose from available selections.

Fabric dying and painting classes are common as choices for quilt classes sponsored by quilt guilds (local and state quiltmakers clubs).

QUILT STITCHES

Quilters exercise more control over stitch designs and quilt patterns than over fabric designs. Quilting stitches often outline the patchwork or appliqué designs providing a secondary level of design complexity to complement the obvious patchwork designs on the basic design level. The Country Crossroads Quilt Guild's 1998 raffle quilt and the Nebraska State Quilt Guild's 1999 raffle quilt both include quilting stitches like this. Country Crossroads Quilt Guild's design features leaves rather than flowers, but both the appliquéd and pieced leaves are outline quilted. This subtle design shows up more on the back of the quilt than on the front of the quilt. The Nebraska State Quilt Guild's "A walk on the wild side" includes more realistic details with a combination of palmate leaves, lanceolate, cordate, palmately lobed, and even palmately compound leaf shapes and palmately lobed leaves like maple leaves and pinnately lobed oak leaves. The state quilt also includes outline quilting. The realistic or figurative images in both cases depend on the shape of the pattern on the front of the quilt, however, they are most obvious on the back, where the colorful designs do not distract from the stitch designs. Quilting stitches may also be used to add details not available in the pieced or appliquéd designs, as the cross-hatch quilting Stehlik used in a small wallhanging (Stehlik 1986). Stehlik's sunflower block, seen from the reverse of the wall hanging, shows the outline of the sunflower as well as the center design (Fig. 1).

QUILT PATTERNS

The wildflower images most readily recognized, in contrast to the fabric designs, and the very subtle quilting designs, appear in the appliqué or pieced work designs (Brackman 1993a, 1993b). Most quilters follow patterns designed by other quilters, but a few of them design their own patterns. Some of the designs have been developed by quilters, and some by artists who may not quilt (Waldvogel 1995). Designs such as "Grandmother's Flower Garden" have been passed down for generations (Brackman 1993a); others are developed every day. This brief history of a few floral quilt designs shows different degrees of verisimilitude in plant anatomy used by North American prairie quilters, quilt designers, and quilt fabrics.

FLOWER GARDEN BLOCK PIECEDWORK

The flower garden quilt, by virtue of its name, memorializes cultivated flowers rather than wildflowers, but its piecing technique typifies many quilts. The quilter may apply or appliqué patches to the top of a larger patch of fabric (Brackman 1993a).

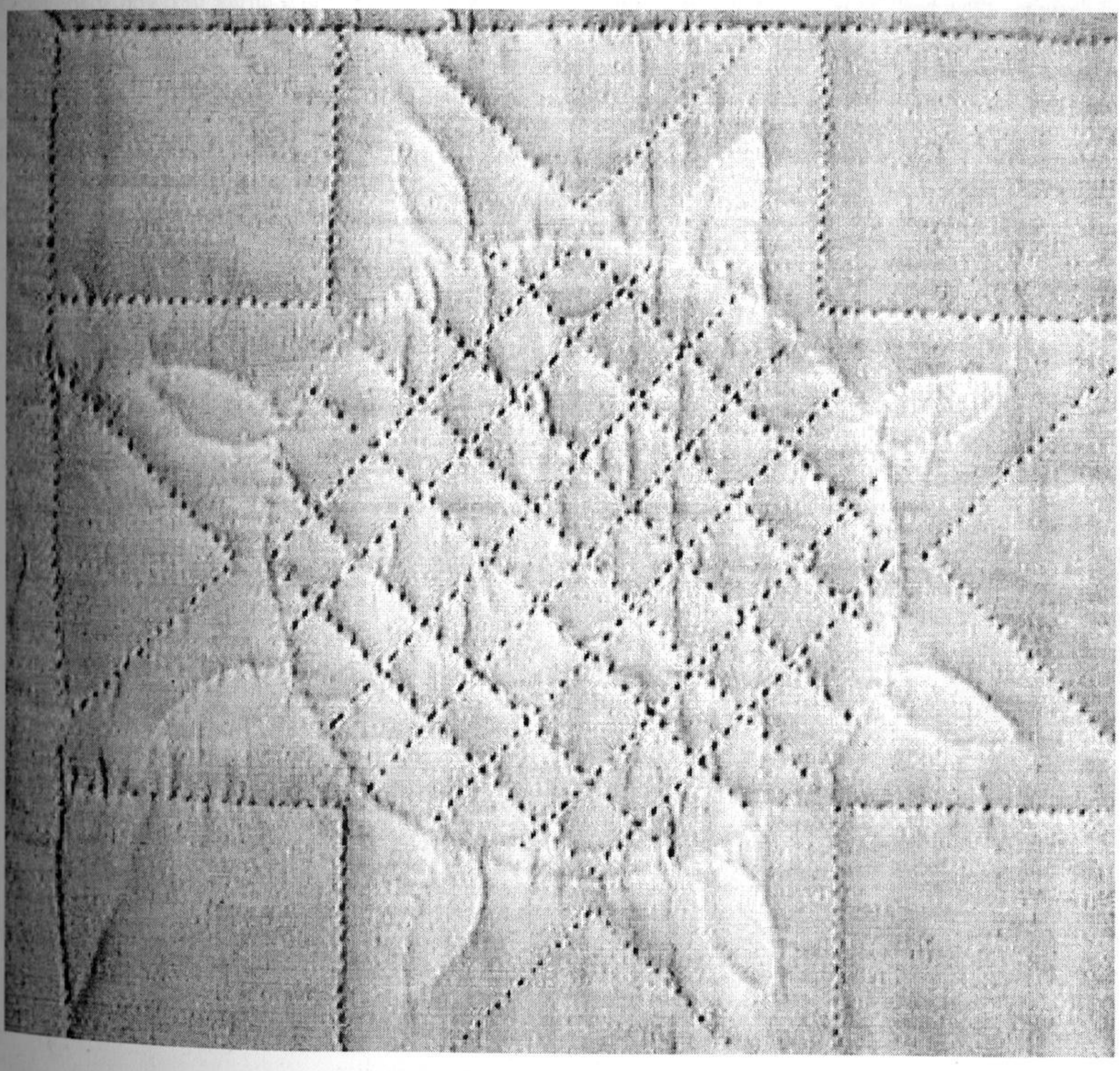

Fig. 1. Quilting stitches as seen from the reverse on Stehlik's (1986) quilt.

Because of the difficulty of completing a bed-sized top, quilters usually work in patches known as blocks. After all of the block designs are completed, then the quilter pieces the blocks together to complete the quilt top. (One exception to this is the wholecloth quilt which includes only stitch designs. Few quilters undertake this style design because of the large blocks of fabric involved. Also, most wholecloth quilts are white or cream colored and keeping them clean as the quilter stitches lines closer than one inch over a 70-inch by 90-inch average-sized cover is very difficult.)

Piecing is often called patchwork, and the pieces are called patches (Brackman 1993b). To aid in the distinction between pieced work and appliqué, the term "pieces" will be used to refer to small pieces of cloth that are joined together at their edges to form floral designs. "Patches" will be used in connection with appliqué designs.

Because it is easier to sew straight lines than curved lines when joining pieces, most pieced quilts portray their natural counterparts abstractly or figuratively, although with modern foundation piecing techniques the details in the flora have become far more realistic. The 6-sided shape of the patches in "Grandmother's Flower Garden" quilts does not allow for realistic design elements as this small wall hanging shows. Dillow (1995) pieced the wall hanging "Grandmother's Fall Garden" for a quilt auction held at QuiltNebraska '94. Close inspection identifies more or less realistic floral designs in the fabrics which form the middle of each petal in 6 of the 8 blocks. This type of alignment which places similar designs in the same place in each block is called fussy cutting and takes a little more fabric than simply cutting the blocks side by side, but it adds to the symmetry and complexity of the overall quilt design.

Dillow (1995) used similar colors in "Grandmother's Fall Garden" to those found in "Honeycomb Patch," an antique quilt which originated in Indiana about 1870-1880 . The "Honeycomb Patch" includes diamonds to develop a larger hexagon shape around each circle of hexagons which are then pieced together with triangles (Fig. 2).

The "Grandmother's Flower Garden" pattern was one of the 2 designs most frequently registered during the Nebraska Quilt Project, 1987-1989 (Crews and Naugle 1991). Although Dillow's original quilt shows that the pattern has been around for more than

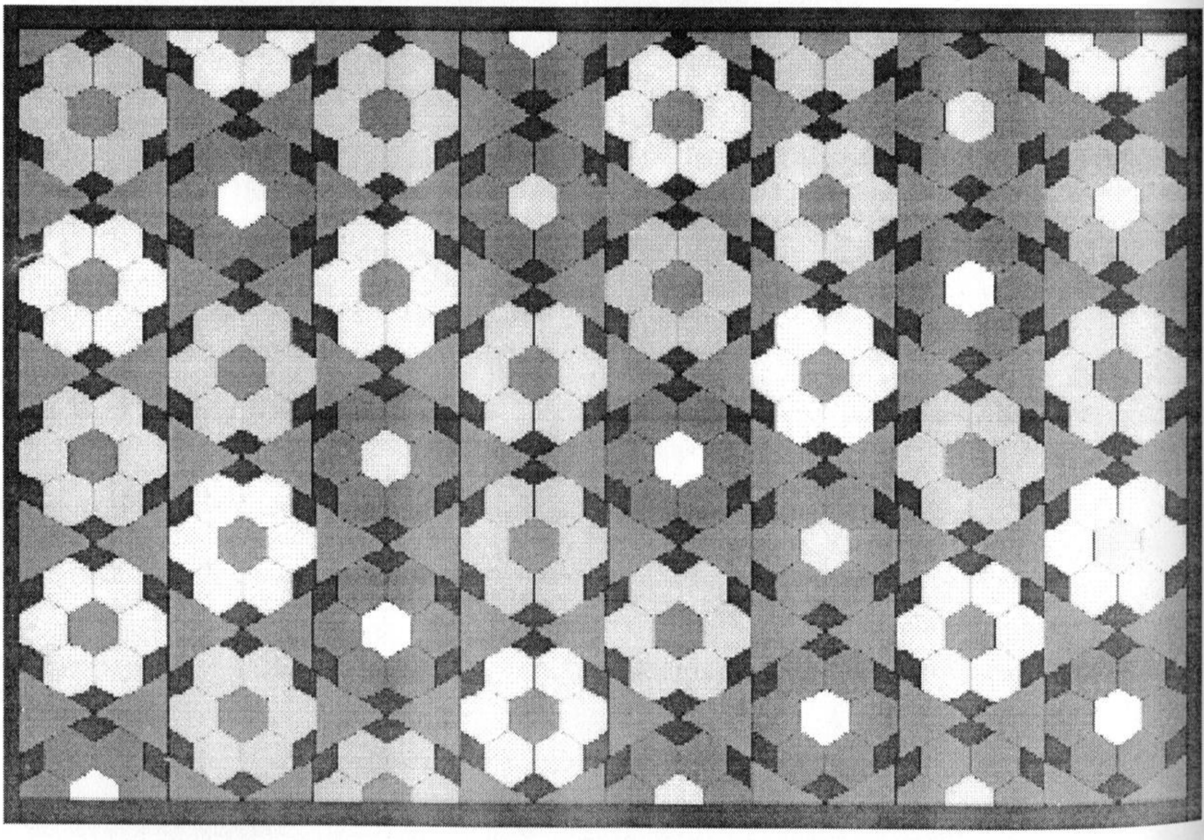

Fig. 2. Honeycomb design by Dillow (1995).

100 years, it is best known in quilts from the 1930s and 1940s (Naugle et al. 1991).

While the "Grandmother's Flower Garden" quilt pattern obviously focuses on cultivated, rather than wild flowers, it identifies both a common piecing technique and the abstract, figurative images typical of quilt designs.

APPLIQUÉ

Another type of quilt design is appliqué, where patches of fabric are applied to the general background. Appliqué adds patches to the top of the quilt in various ways. The raw edges were often covered with button hole stitches in early appliqué. Several other methods for turning the raw edges under in order to finish them include pressing the edge under before the seamstress begins stitching, or turning the edge with the needle as she works.

Broderie perse appliqué is one of the oldest forms (common from 1750 to 1840), which Brackman (1993a) identified with English derivation. Broderie perse is a less-well-known type of appliqué known for its particular floral images pertinent to this study. Brackman (1993a) noted major themes were the flowering tree (the tree of life) and a central vase holding many blooms. These were true-to-life depictions of peonies, chrysanthemums and roses. Color schemes were naturalistic greens, reds, browns, and yellows. Because of the age of quilts with broderie perse, few remain outside major collections. Chintz cloth was fairly expensive at the turn of the eighteenth century, so quilters cut the main images, the tree of life, or the flower urn out of the chintz and then appliquéd it to the less expensive muslin background, extending the design by applying corner elements in a variety of ways.

In general, curved lines are easier to complete with appliqué than with pieced work, so many appliqué patterns are more realistic than pieced patterns. Several modern pattern designers who

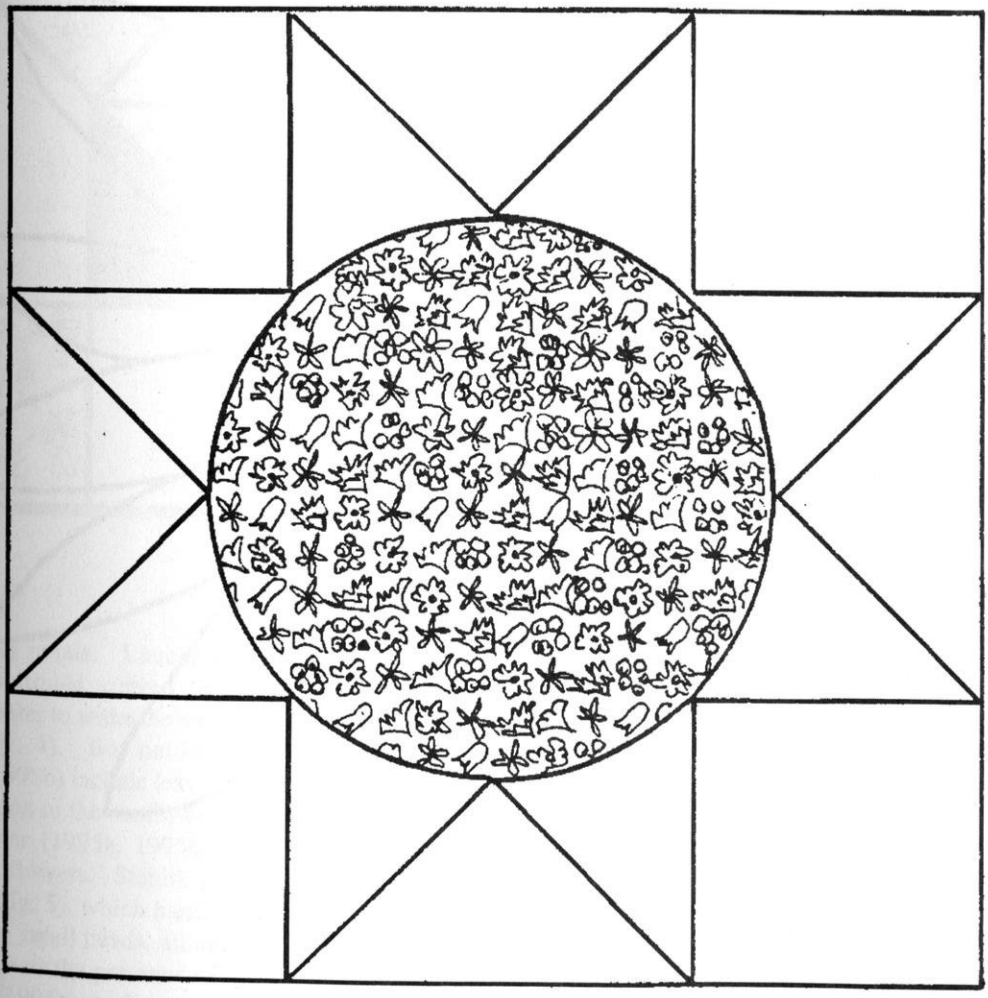

Fig. 3. Stehlik's (1984) sunflower.

feature wildflowers include Stehlik (1984, 1986), Laucomer (1995, 1996), Halvorsen (1996, 1997), and Armstrong (1998).

Although many gardeners grow sunflowers, their high recognition and frequent appearances on roadsides place them deservedly among the most frequently pieced or appliquéd wildflowers on quilts. "Forget Me Not" refers to a memory quilt rather than the flower (Halvorsen 1997), but Halvorsen appliquéd a stylized flower basket with 3 unidentifiable flowers into the May block. The basket automatically suggests more of a cultivated, garden flower, but the August block features a sunflower with the large dark center and 3 sets of parallel leaves on the stem. The inclusion of the leaves probably makes Halvorsen's the most realistic sunflower compared in this study, since the *Heliopsis* sunflower has opposite leaves (Nelson 1979). Although Halvorsen's leaves are ovate, they lack the petioles and toothed edges of real sunflowers. And the large center and small leaf border of the flower is more reminiscent of the common sunflower (*Helianthus annuus* L.) than the rough sunflower (*Heliopsis helianthoides* L.), but this sunflower has alternate, rather than opposite leaves (Nelson 1979). Stehlik's (1984) sunflower pattern (Fig. 3) pieces pointed petals into the background fabric and then appliqués a large circle of fabric to the center of the flower. It simply gives the abstract

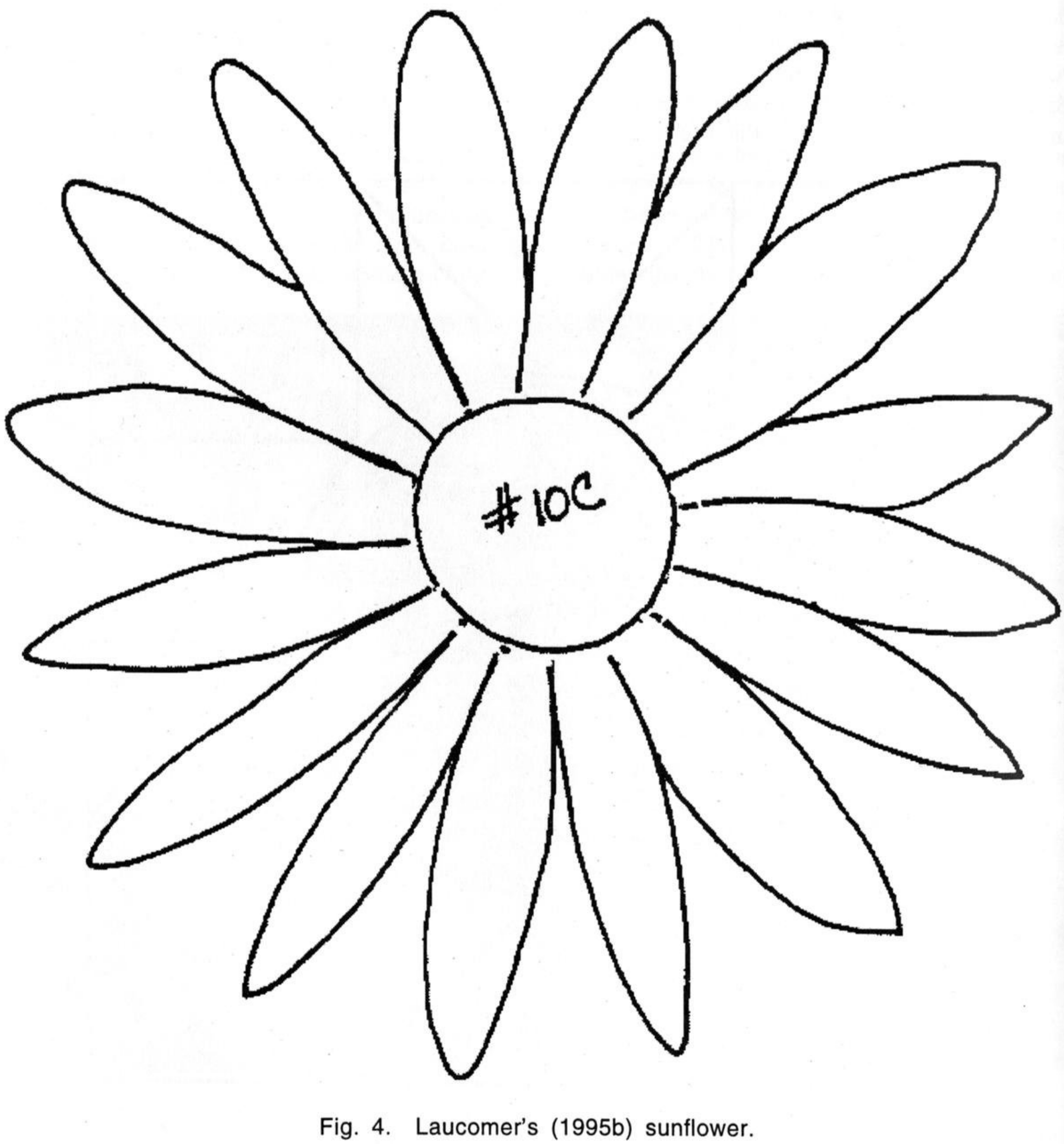

Fig. 4. Laucomer's (1995b) sunflower.

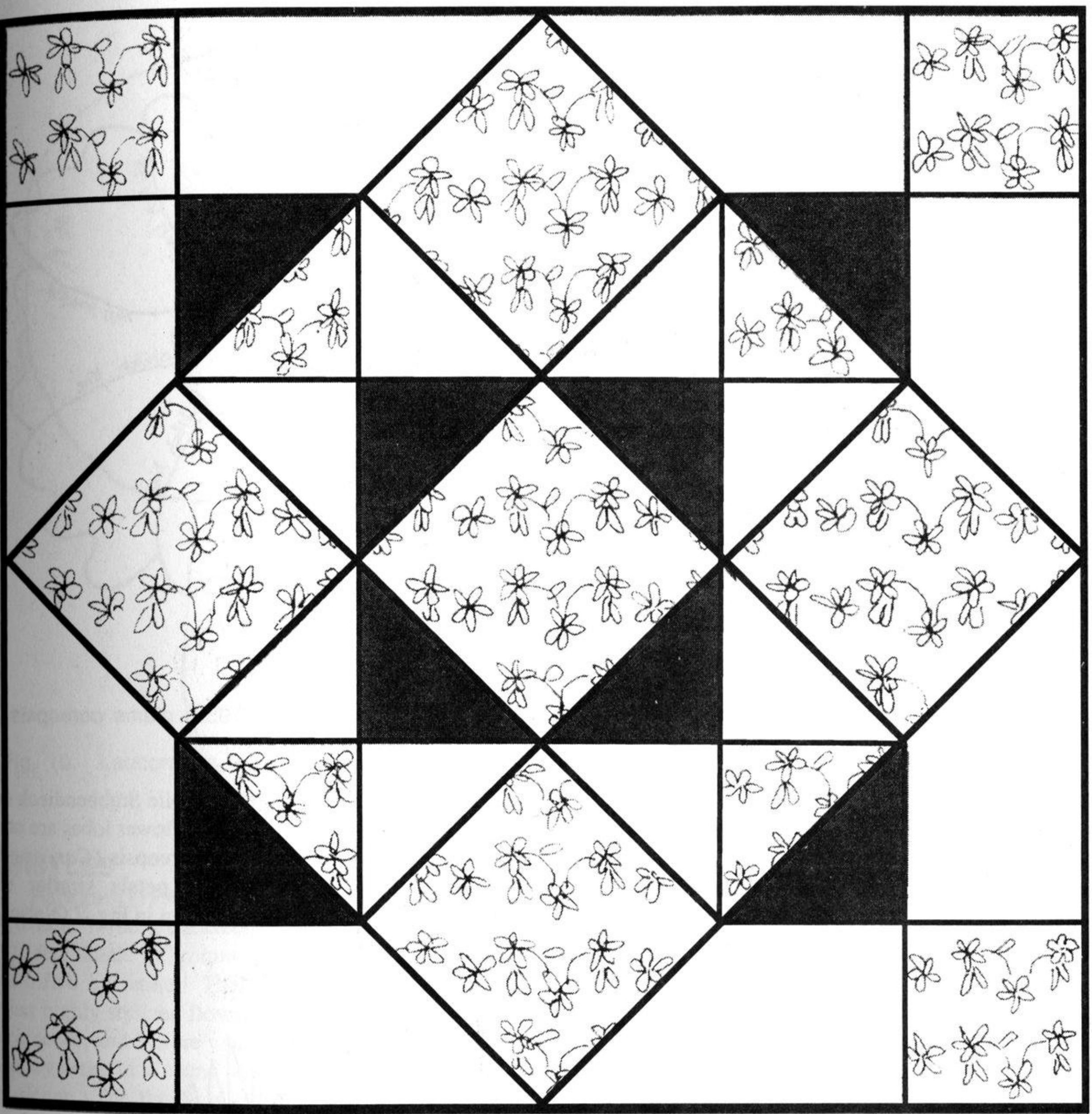

Fig. 5. Stehlik's (1984) goldenrod.

image of the petals. Laucomer's (1995b) pattern includes appliquéd curved petals as well as the appliquéd center to make the shape of her petals more realistic (Fig. 4). But neither Stehlik (1984) nor Laucomer (1995b) include leaves on their flora.

In addition to the sunflower, both Stehlik (1984) and Laucomer (1995a, 1995b) portray other gold-colored wildflowers. Stehlik pieces a very abstract goldenrod (Fig. 5), which hardly hints at the clusters of flowers in small heads, although her use of green patches suggests the presence of leaves. Laucomer's goldenrod (1995a) outlines the irregular blossom cluster and includes leaves, too (Fig. 6). All of Laucomer's (1995a, 1995b) designs feature the curved petals of the wildflowers because of their appliqué technique, but some of the yellow or gold-colored flowers are difficult to distinguish. Laucomer's (1995b) sunflower (Fig. 4), plains coreopsis (*Coreopsis tinctoria* Nutt.) shown in Fig. 7, and sneezeweed (*Helenium* spp.) shown in Fig. 8 all include the same circular shape with indentations to distinguish between the petals, rather than individual petals. Only the petal shapes distinguish the 3 similar flowers in their design forms, but the color

Fig. 6. Laucomer's (1995a) goldenrod.

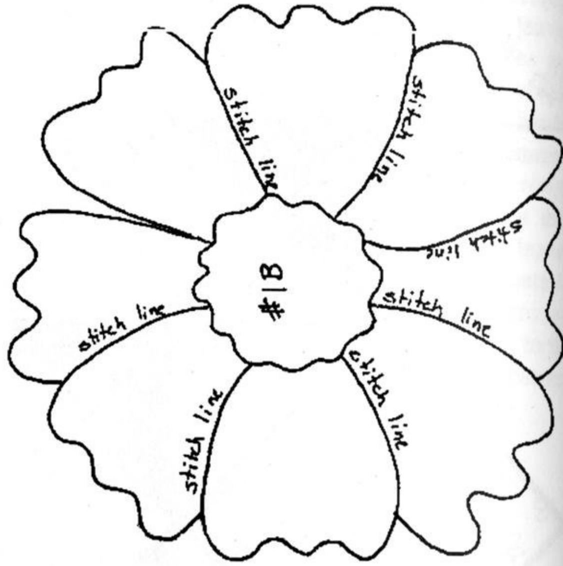

Fig. 7. Laucomer's (1995b) plains coreopsis.

photo on the front of Prairie wildflowers 2 shows a lighter colored center for the sneezeweed than for the sunflower or coreopsis (Laucomer 1995b). The sneezeweed (Fig. 8) accurately reflects the 3-lobed petals of the realistic corolla (Stubbendieck et al. 1994). In contrast, Laucomer's coreopsis (Fig. 7) appears to have 3-lobed petals, while Stubbendieck et al. (1994) pointed out that its ray flower lobes are not all equal in length. Whorled coreopsis (*Coreopsis verticillata* L.) has notched petals similar to Laucomer's plains coreopsis shown in Fig. 7 (Nelson 1979).

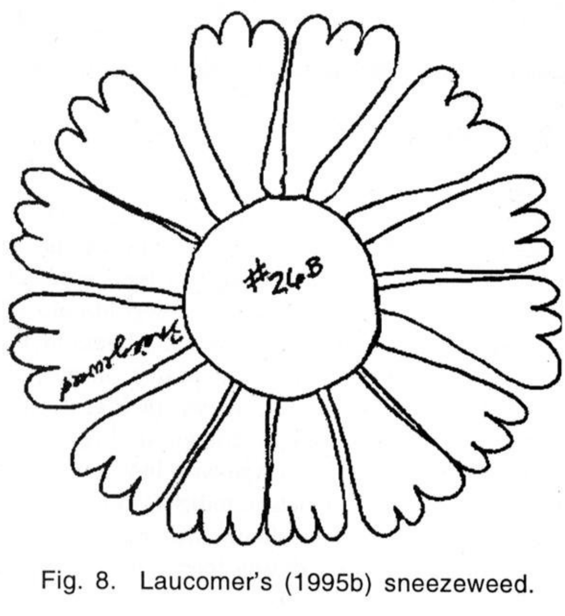

Fig. 8. Laucomer's (1995b) sneezeweed.

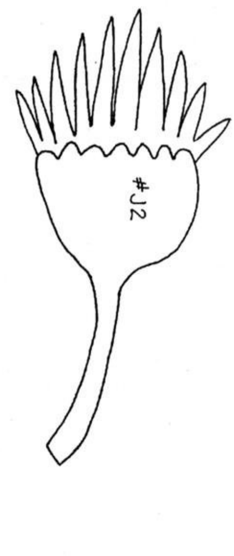

Fig. 9. Laucomer's (1995a) Platte thistle.

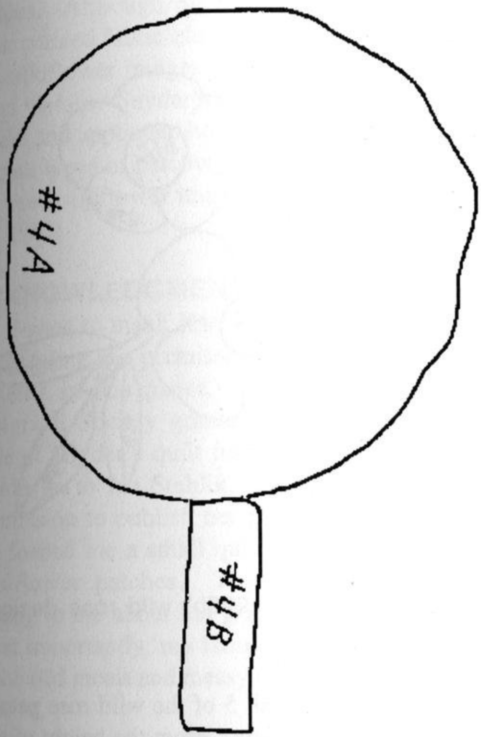

Fig. 10. Laucomer's (1995b) globe thistle.

THISTLES

Halvorsen (1996) includes dandelion (*Taraxacum officinale* Weber), cocklebur (*Xanthium strumarium* L.), and thistle (*Circium* spp.) images identified by name. There are also 3 other highly stylized flower designs in a frog scene, and 3 more with a vine and 2 topiary trees in a scene with a woman gardener. The thistle is still a generic violet-colored thistle with too little detail to identify it as a bull thistle (*C. vulgare* Savi) or a musk thistle (*Carduus nutans* L.) (Nelson 1979, Farrar 1990). Although Laucomer's (1995a) Platte thistle in Fig. 9 includes even fewer features than Halvorsen's generic thistle, Laucomer (1995a, 1995b) included some of the most complete details for quilt blocks available. Laucomer (1995b) recognized different thistle species in her block titles, and the white color fits the species name. She also includes the globe thistle seen in Fig. 10.

When Laucomer developed her wildflower designs, she included detailed information about the color and shapes of the wildflowers which supports her realistic understanding of wildflowers as well as aiding quilters in their attempts to complete accurate designs. Although Laucomer's (1995a) pattern pieces (as the goldenrod block cited earlier illustrates in Fig. 6) may lack details (the block is simply one piece of fabric with whorled and undulate edges), her note adds that "Canada [g]oldenrod has clusters of tiny gold flowers arranged in a plum shape".

Another note identified a point where artistic design clashed with reality when Laucomer wrote, "[p]uncture [v]ine seems to have 1 flower with each group of leaves, but the block was so bare!" Stubbendieck et al. (1994) pictured puncturevine (*Tribulus terrestris* L.) with even, pinnately compound, leaflets, whereas Laucomer's (1995a) puncture-vine placed the leaflets almost alternate (Fig. 11), rather than pinnately on the rachis. Careful positioning by the quilter can correct that difference.

The most realistic, but least common, quilt designs are developed by surface embroidery stitches. Ronning and Crews (1991) showed embroidered quilts that include a variety of embroidered wildflowers. Some of the best examples of realistically embroidered wildflowers appear in C. P. Griswold's crazy quilt, pieced and embroidered during the year that she "sat her claim" in Sioux County, Nebraska, and the embroidered State birds and flowers quilt by B. B. Laughlin (Crews and Naugle 1991).

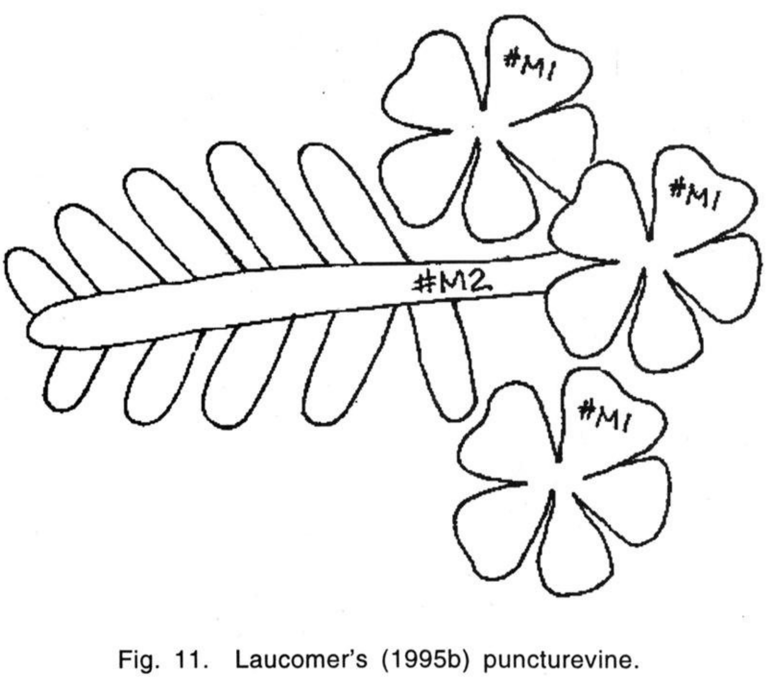

Fig. 11. Laucomer's (1995b) puncturevine.

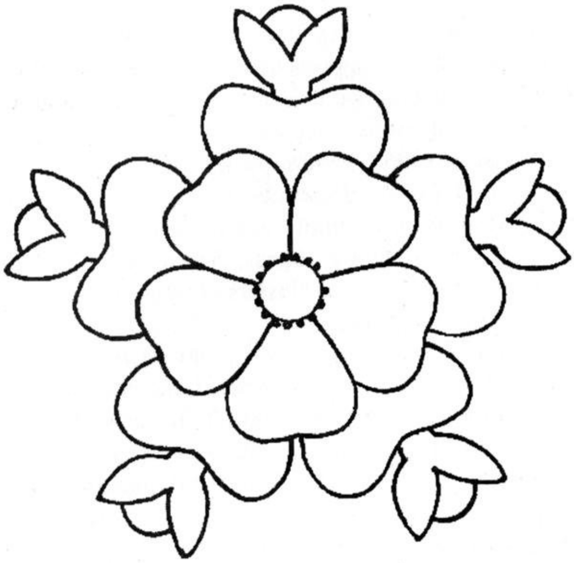

Fig. 12. Stehlik's (1984) wild rose design.

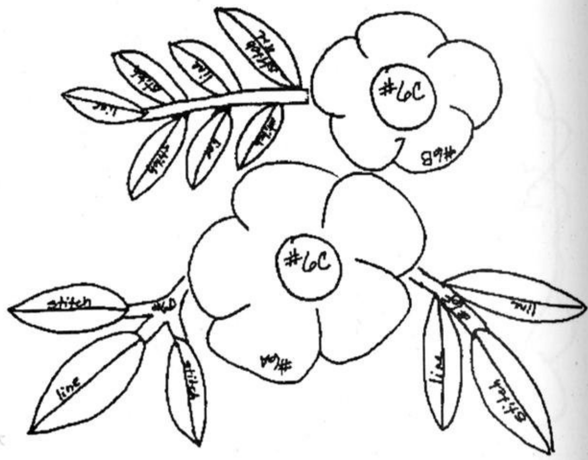

Fig. 13. Laucomer's (1995b) wild rose design.

NEBRASKA QUILTERS AND QUILT DESIGNERS

As each design example moves closer to its origins on the prairie, the importance and accuracy of the flora grows. Stehlik (1984) and Laucomer (1995b) both included wild rose (*Rosa* spp.) designs (Fig. 12 and Fig. 13), but the best-known wild-rose design appears in Snyder's award-winning quilt, "Flower Basket Petit Point" (Snyder and Yost 1963). Snyder always appreciated nature and pieced blocks outdoors from the time she began piecing (while watching cattle at the age of 5 or 6) to her prime quilting years (when she drove her husband around their Tryon, Nebraska, ranch to fix fence, or when she followed Bert to recreational fishing holes in Wyoming). Snyder's granddaughter, Josie Forell, told me about Snyder going outside to draw the picture of a lily which she translated into a quilt block, and this translation of her countryside frequently appears on Snyder's quilts.

The formal basket bouquet in "Flower Basket Petit Point" appears to be of cultivated flowers, rather than wildflowers, but the "Rose of Life" border reminds me of wild roses. The formal needlepoint style makes realistic detail difficult, as does the narrow repetition format of the border, but here Snyder merged 2 types of flora. To complete the central block design, Snyder took the rose out of the basket and added a bud and stem to the triangles which completed the central block design. These large roses are obviously cultivated, but Snyder added a side view to the corner border roses appropriate to wild roses. A few of the petals, not all 5 of the wild rose petals, can be seen in the side view. From the height of the rose border, one would assume Snyder's hillside was covered with western wild roses (*Rosa woodsii* Lindl.), rather than the shorter prairie wild roses (*Rosa setigera* Michx.). Again, the multiple leaf shapes recognize the variety in natural roses, although the space in the border and the design style made it difficult for Snyder to illustrate the many oval to ovate leaflets on either the western wild rose or the prairie wild rose variety. Another problem with the technical accuracy of Snyder's wild rose is the alternate leaves rather than the pinnate formation found on both cultivated and wild roses. Still, Snyder used more than 2 leaf shapes, and the open flowers in the corners and at the bottom of the vine recognized the simplicity of wild roses in comparison with the cultivated rose from the basket.

CONCLUSION

These sample images of cultivated and wildflower images in prairie quilts serve only as an introduction to the interrelationships between the quilt world and the world of scientific prairie studies. The fabric, stitches, and pieced and appliquéd images often appear in abstract form. However, many times surprising details surface, illustrating the knowledge and love of the quilters for their surroundings. One of the best examples of these images is Snyder's (1942) best-known quilt, "Flower Basket Petit Point." With its cultivated flower basket blocks and wild rose border, Snyder combined the cultivated and wildflower images. Although no floral images appear on her plain colored fabric blocks, her quilt stitches outlined the wildflower images on the border, as well as the floral baskets. Snyder's combination of pieced basket blocks and appliquéd border designs included the best of both types of patchwork, for a thorough review of the best wildflower images in prairie quilts (Snyder and 1963).

ACKNOWLEDGMENTS

I want to thank Kate Laucomer and Sara Dillow for granting me permission to reprint some of their patterns in this paper. Also, the Nebraska State Historical Society granted me permission to use a slide of Snyder's quilt for my presentation. Special thanks go to Jan Stehlik. She not only granted me permission to publish her patterns in this paper, but she loaned me a small quilt she had made from her wildflower patches. Thanks to Josie Forell for talking to me about her grandmother, Grace Snyder. Most importantly, my family encouraged me in spite of the odd meals and messy house my research always spawns.

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SMOOTH BROME AS A POTENTIAL RESERVOIR OF PLANT DISEASES

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Abstract: Introduced plants are often tolerant of, or only mildly susceptible to, plant diseases that are capable of causing losses to native plant species and/or to agronomically important crops. This paper focuses on smooth brome (*Bromus inermis* Leyss.), which has become a successful invader. Several plant pathogens that infect cereal crops are also reported on smooth brome. Diseases include damping off caused by several species of *Pythium*; ergot caused by *Claviceps purpurea*, take-all caused by *Gaeumannomyces graminis* var. *tritici*, and Cephalosporium stripe caused by *Cephalosporium gramineum*. In part, the success of introduced plant species is due to their immunity, tolerance or mild susceptibility to diseases to which native plants or agricultural crops are susceptible. Introduced plants may sustain pathogens during changes in the environment until a more susceptible host is available.

PROCEEDINGS OF THE NORTH AMERICAN PRAIRIE CONFERENCE 16:46-48

Key words: *Cephalosporium gramineum*, Cephalosporium stripe, *Claviceps purpurea*, damping off, ergot, *Gaeumannomyces graminis* var. *tritici*, *Pythium*, take-all.

Of the most economically important weeds in the prairie ecosystem, most are introduced plant species. Baker and Stebbins (1965) defined weeds as follows: "A plant is a weed if, in any specified geographical area, its populations grow entirely or predominantly in situations markedly disturbed by man (without, of course, being deliberately cultivated plants)." In agricultural and rangelands, lands that are disturbed directly or indirectly by activities of humans, weeds are classified into four groups:

1. Primary noxious weeds.
2. Secondary noxious weeds.
3. Locally noxious weeds.
4. Common weeds.

This classification represents a continuum from primary noxious weeds, which are the most serious and difficult to control or to eradicate once they have been established, to common weeds, which can be controlled with proper management (Kinch et al. 1975).

While the fate of introduced plant species cannot readily be predicted, successful plant invaders share several common characteristics (Baker 1986, Bazzaz 1986). These characteristics include, but are not limited to:

1. Rapid growth.
2. Flowering and seed set under a wide range of temperature conditions and day lengths.
3. A high degree of "phenotypic plasticity."
4. A high population growth rate.
5. Autogamous, wind pollinated or serviced by generalist pollinators.
5. Long range seed dispersal ability.
6. Rapid response to availability of resources.
7. Seed and/or crop morphology mimicry.

Successful plant invaders evolved competitive strategies in their own environment and are now for the most part freed from the predator-prey relationships and competitive species against which they evolved. In their new environment such strategies allow them to become successful competitors.

As part of their competitive advantage, introduced plants are often tolerant of, or only mildly susceptible to, plant diseases that are capable of causing losses to native plant species and/or to agronomically important crops. While plants that exhibit tolerance to a plant disease are susceptible to the disease, they are, if infected, still able to grow, survive, and reproduce. On the other hand, plants that do not exhibit tolerance and are susceptible to the same disease lack the ability to resist the disease or attack by the pathogen. They exhibit symptoms that vary from mild to the death of the plant (Agrios 1988). Native plant species and agricultural crops often exhibit symptoms of disease that result in loss of vigor and/or yield. In addition, different parts of plants may be susceptible to different pathogens: roots, shoots, floral parts, fruit and seed may become infected. Thus, such diseases, while of little consequence in the introduced species, may severely

Fig. 1. Smooth brome growing in Lake Herman State Park in eastern South Dakota. These plants are successful invaders in the prairie lands in the park.

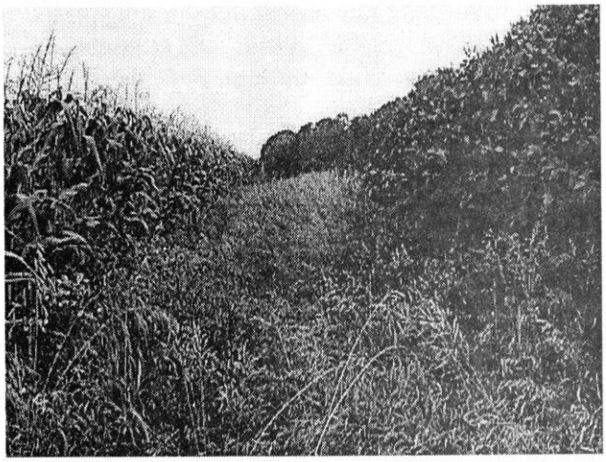

Fig. 2. A near monoculture of smooth brome growing between a cultivated corn and a shelterbelt in eastern South Dakota.

reduce yield or be fatal to susceptible native plant species and/or agricultural crops.

Smooth brome (*Bromus inermis* Leyss.) is an example of an introduced plant that is important on the prairie (Fig. 1 and Fig. 2). Smooth brome was introduced from Europe and cultivated as hay and pasture grass from Minnesota to New Mexico and Arizona, west to Washington and east to Michigan, and has also been used for reseeding. As a successful colonizer, smooth brome develops dense colonies from creeping rhizomes (Hitchcock and Chase 1971), and as these colonies die back at the end of the growing season, they form dense mats that aid in crowding out other species (Fig. 3.).

Spread of diseases may also occur from hay or contaminated machinery.

Several plant pathogens that infect cereal crops are also reported on smooth brome. Plant pathogens may be transmitted by air, soil, water, infected plant debris, insects or nematodes, and introduced plants. Diseases caused by fungal pathogens include "damping off," "root browning," and "necrosis" caused by several species of *Pythium*, "ergot" caused by *Claviceps purpurea*, "take-all" caused by *Gaeumannomyces graminis* var. *tritici*, and "Cephalosporium stripe" caused by *Cephalosporium gramineum* (Farr et al. 1985, Weise, 1977). Maintenance of a pathogen during periods when a field is not planted to a susceptible agricultural crop may have epidemiological implications.

In part the success of introduced plant species is due to their immunity, tolerance or mild susceptibility to diseases to which native plants or agricultural crops are susceptible. Finally, introduced plants may sustain pathogens during changes in the environment.

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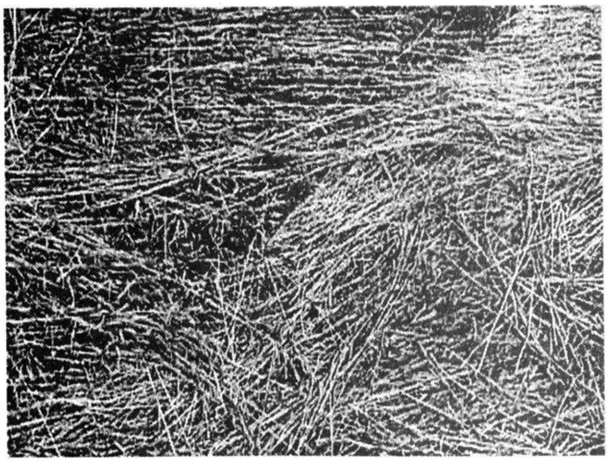

Fig. 3. A dense mat formed at the end of the growing season by senescent smooth brome.

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SPRING UP, FALL DOWN

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Abstract: In the spring, the inflorescence spikes of prairie perennials exhibit anthesis from below upwards: e.g. *Petalostemum purperea*. In the fall, they flower from the top down: e.g. *Liatris mucronata*. Other examples are reviewed as are some exceptions, and I extend this observation the compound dichasia of the fall-flowering *Silphium integrifolium*.

PROCEEDINGS OF THE NORTH AMERICAN PRAIRIE CONFERENCE 16:49-50

Key words: compound dichasia, inflorescence spikes, prairie forbs, prairie perennials.

The original prairie of Texas was first ravaged by plow and by overgrazing during the 1860s; that was 140 years (5 generations) ago. Coincidentally, that was also the time of the start of the Industrial Revolution, and the dawn of the modern Scientific Era.

That means that those early farmers and ranchers were not able to realize the effects of the sod-busting and of the overgrazing that they were observing. They could see the losses of fertility, but they could not know why science had not yet reached the prairie front.

THE PHILOSOPHICAL SOCIETIES

In the major cities, things were different. Both here and in Europe science was bringing about a ferment; it was news, it was magic made true. Professors, both real and self-proclaimed, toured the cities, giving talks and demonstrations of marvels. They set on end the hair of young ladies with static electricity from their Wimshurst machines. They made young ladies giggly and senseless with laughing gas. They made solutions change color in front of the audience's very eyes. Those early scientists formed Philosophical Societies where they exchanged information, announced new observations, and asked questions about their significance.

I intend this presentation to be as though it were made to one of those Philosophical Societies. I have made observations, and I want to ask you what they signify.

SPIKES AND RACEMES

In the spring, the prairie is ablaze with colorful flowers of all kinds among the grasses and sedges. Some of those grow as spikes or racemes (Table 1). All of these flower from their base upwards to their top.

As high summer approaches, a fresh wave of spikes and racemes grow. But have you noticed? They flower from above down (Table 2).

Why this difference?

Can you explain it?

EXCEPTIONS

An exception to this pattern is given, for example, by the fall-flowering obedient plant *(Physostegia parviflora* Nutt.*)*. Like its spring-flowering cousin, false dragonhead (*P. augustifolia* Fern.), it too flowers from below upwards.

COMPOUND DICHASIA

There are other kinds of fall species which flower from the top down: those which exhibit compound dichasia. At first glance these seem to be flowering

Table 1. Some examples of spring-flowering species.

Common Name	Scientific Name
bluebonnet	*Lupinus texensis*
chokecherry	*Prunus serotina*
false foxglove	*Penstemon coboea*
obedient plant	*Physostegea pulchella*
prairie larkspur	*Delphinium albescens*
purple dalea	*Petalostemum purpurea*
slender vervain	*Verbena haileyi*
wild hyacinth	*Camassia scilloides*
wistaria	*Wistaria macrostachya*

Table 2. Some examples of fall-flowering species.

Common Name	Scientific Name
blazing star	*Liatris punctata*
goldenrod	*Solidago altissima*
compass plant	*Silphium laciniatum*
white compassplant	*Silphium albiflora*
An Exception	
Stenosiphon (aka false gaura)	*Stenosiphon linefolius*

from below up, but closer examination shows them to be top down. In these, the first terminal inflorescence appears to be a scape, but it carries 2 leaflets halfway up the stem. As the flower develops those leaflets each subtend an axillary stem with a terminal inflorescence. Halfway up their stems, these also have 2 leaflets, and each of these, in their turn, subtend in their axils a stem with a terminal inflorescence, and those have 2 opposite leaflets halfway up their stems. And so it goes on, until fall frost. So although it is growing taller all the time, it is actually flowering from the top down.

Some species of *Silphia* behave like this: e.g. rosinweed (*S. integrifolium* Michx.) Another example is rattlesnake master (also known as button snakeroot) (*Eryngium yuccifolium* Michx.). This species is interesting, because each compound flowering head flowers from the base upwards; thus the plant as a whole has both fall and spring characters.

This report is but a preliminary observation. Is it a worthy subject for further investigation, maybe as a topic for a student thesis?

THE CRONGLE

While you are thinking about the last question, here is another mystery: the crongle. As you wander through a tallgrass prairie, pause to hold the base of a leaf blade between your finger and thumb, and then pull your hand lightly towards the tip. Often you will notice, about halfway up, a brief irregularity; it feels like a bumpy thickening.

If you examine that with your hand lens, you will find the blade is a little narrower at that place, and the surface is transversely rippled, slightly corrugated. Many of the tallgrass species that I have examined show this. When one blade on a stem has it, all on that stem, and all the stems of that clone, have it. I have not yet found more than one crongle on a blade.

Leaf-cutting insects often make their first nibbles at the crongle. A blade sometimes falls over there.

How did it get there? How did the meristem make it? What prompted the meristem to do that? Why?

BRYOPHYTE DIVERSITY IN OPEN TALLGRASS PRAIRIES AND PRAIRIES ALTERED BY STRIP MINING

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Abstract: Historical records from southeast Kansas indicate 90% of the topography was open prairie, with the remaining consisting of riparian vegetation. Before strip-mining began, prairies were typically maintained by natural disturbances such as fire or grazing by native mammals; consequently, the introduction of strip-mining significantly altered this ecosystem. This is the first study conducted which compares bryophyte diversity between open tallgrass prairies and prairies altered by strip-mining. Bryophyte samples were collected from 6 strip-mined areas within Crawford and Cherokee counties from August 1996 to December 1996 and compared with previous bryophyte studies from 7 open tallgrass prairies in the Great Plains region. Altogether, 555 bryophyte samples were identified from the altered prairie. The 6 altered prairies contained 8 species of liverworts among 5 genera and 4 families, and 71 species of mosses among 43 genera and 22 families. Twenty-three species of mosses were reported for the first time in Crawford County and 32 for Cherokee County. Five new additions to the bryoflora of Kansas were *Isopterygium tenerum* (Sw.) Mitt, *Micromitrium austinii* Aust., *Sphagnum fimbriatum* Wils. *ex* Wils. & Hook. *f. in* Hook., *Sphagnum lescurii* Sull *in* Gray, and *Sphagnum platyphyllum* (Lindb. *ex* Braithw.) *ex* Warnst. Bryophyte samples collected from 7 open tallgrass prairies included 25 species of liverworts distributed between 14 genera and 10 families and 89 species of mosses between 46 genera and 21 families. Sørenson's coefficient of community similarity index was used to determine bryophyte diversity between the altered prairies and open tallgrass prairies. These results suggest there is not a higher diversity of bryophytes growing on altered prairies when compared to open tallgrass prairies.

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Key words: Cherokee County, Crawford County, *Isopterygium tenerum, Micromitrium austinii,* Sørenson's coefficient of community similarity index, southeast Kansas, *Sphagnum fimbriatum*, *Sphagnum lescurii*, and *Sphagnum platyphyllum.*

Historical records from southeast Kansas indicate that 90% of the topography was open prairie, with the remainder consisting of riparian vegetation (Anonymous 1867-1875, Anonymous 1867-1898, Powell 1970). Before strip-mining began, prairies were typically maintained by natural disturbances such as fire or grazing by native animals (Mooney et al. 1981, Wright and Bailey 1982, Collins and Barber 1985).

In the late 1800's and early 1900's, heavy machinery was used to strip-mine the prairie (Powell 1970) creating large and sometimes deep depressions which eventually filled with water. In addition, the mining operation altered the topography of the open prairie, decreasing the chances of natural wildfires. These changes in topography resulted in an ecosystem having characteristics which contributed to the increase in woody plant growth. This woody plant growth produced a shaded environment for part of the year which affected soil temperature and moisture, humidity, and the intensity of light reaching the understory vegetation.

Bryophytes can grow in nearly every type of habitat, and although many can reproduce asexually, water is essential for sexual reproduction (Wyatt 1982, Schofield 1985, During and Van Tooren 1990). Since strip-mined land has depressions capable of water storage, this provides a suitable habitat for both woody plants and bryophytes.

This is the first study conducted which compares bryophyte diversity between open tallgrass prairies and prairies altered due to strip-mining. This research was guided by the hypothesis that there would be greater diversity of bryophytes growing on altered prairies (strip-mined land) compared with bryophytes growing on open tallgrass prairies. The purpose of this study was to (1) collect and identify bryophytes on selected strip-mined sites in Crawford and Cherokee County, Kansas, and (2) compare the diversity of bryophyte samples collected from these areas with previous studies of bryodiversity from open tallgrass prairies.

PRAIRIE BRYOFLORA

Bryofloristic studies have been sporadic throughout the past century in parts of Kansas, Missouri, Arkansas, Oklahoma, Nebraska, Iowa and Illinois (Rau 1884; Hague 1934; Hatcher 1952; Duncan 1954; Thomson 1961; Smith 1966; Zales 1971; Churchill et al. 1981; Redfearn 1983; Timme 1983, 1987; Merrill 1991; Nonnenmacher and Timme 1995; Timme 1997). Among these bryological studies, few have been conducted on prairies of the Great Plains. Collections on open tallgrass prairies have been conducted in north central Kansas (Merrill 1991), northeastern Kansas (Duncan 1959), southwestern Missouri (Timme 1983), western Arkansas (Timme 1987), northwestern Iowa (O'Keefe van der Linden and Farrar 1983), and southwest Illinois (Zales 1971). Few bryophyte collections have been conducted as part of prairie floristic studies in the Great Plains region (Glenn-Lewin and Ver Hoef 1988).

Bryophytes quickly recolonize areas destroyed by fire (Duncan and Dalton 1982; Moul and Buell 1955; Southhorn 1976). Duncan and Dalton (1982) suggested that *Marchantia polymorpha* (L.), *Funaria hygrometrica* (L.), *Ceratodon purpureus* (L.), and *Bryum sauteri* (L.) are a few pioneering species found on burned substrates. *Polytrichum juniperinum* Hedw., and *Campylopus introflexus* (Hedw.) Brid. are often found on a burned substrate within the second year.

MINED LAND BRYOFLORA

Bryophyte studies on altered prairies (strip-mined land) have been less frequent than on open prairies. Of these mined land studies, even fewer were found to include open tallgrass prairies (Carvey et al. 1977, Rastorfer 1981). Among the few researchers that have conducted these bryophyte studies, Carvey et al. (1977), Glime et al. (1982), Wyatt (1982), Engelmann and Weaks (1985), and Glime and Vitt (1987) each have different opinions in the functionality of the bryoflora in the early succession of plants on barren ground. Some scientists believe bryophytes only contribute to the "composition" of the ecosystem (Carvey et al. 1977), whereas others believe they play a primary role in early successional stages of an ecosystem (Glime et al. 1982, Wyatt 1982, Glime and Vitt 1987).

Glime and Vitt (1987) studied mosses growing at various vertical distances from a stream bank. Their study suggested bryophyte diversity increased with distance from the water's surface. They suggested the increased vertical distance from the stream gave bryophytes a physical advantage over decreased distances from the stream. Glime and Vitt (1987) also suggested bryophytes submerged or close to the water would be affected more by physical and chemical factors than those farther from the water's surface.

Glime et al. (1982) studied bryophyte succession from an alkaline marsh to a *Sphagnum* bog. Their study suggested *Sphagnum* may contribute to the acidic nature of an alkaline marsh, therefore, contributing to succession of vascular plants which inhabit the area.

Carvey et al. (1977) observed bryophytes growing in unique habitats on coal spoils of southern Iowa. This study suggested bryophytes do not establish themselves before vascular plant growth. Carvey et al. (1977) concluded bryophyte diversity only increased as vascular plant growth increased. This conclusion was based on the assumption that bryophytes require substrates that have been stabilized and protected from erosion prior to their inhabitance.

Rastorfer (1981) conducted a bryofloristic study on reclaimed mined land in Grundy County, Illinois, where the topsoil was continuously eroding. Rastorfer (1981) concluded that bryophytes play a primary role in stabilizing the soil for the future growth of grasses and forbes. This study suggested bryophytes add cohesion to the soil, reduce soil erosion, reduce heavy-metal toxins, and enhance nitrogen fixing blue-green algae.

Engelmann and Weaks (1985) studied bryophyte diversity along streams in strip-mined land areas of West Virginia. Their study reported bryophyte diversity decreased with disturbance, but observed certain species growing in specific areas. Engelmann and Weaks (1985) concluded that bryophytes may benefit mined land areas by stabilizing the soil moisture and pH for the initial growth of grasses.

A physiological study conducted by Dilks and Proctor (1974) suggested bryophytes can remain viable after long periods of desiccation. Some can propagate after years in herbaria collections. When considering Dilks' and Proctor's (1974) research, it is reasonable to suggest that bryophytes can remain viable during long periods of desiccation and reproduce in the harsh environment of coal spoils.

METHODS

Site Selection

Six study sites, totaling 586 ha, located in Crawford and Cherokee counties in southeast Kansas were selected for this study: three in each county. The location of each study site was determined based on information obtained from the Mined Land Wildlife Area Map (Anonymous No Date) provided by the Kansas Department of Wildlife and Parks. All study sites chosen were mined between 1914 and 1947 (Brady 1998) and maintained by the Kansas Department of Wildlife and Parks since 1972. Legal descriptions for each site were obtained from topographic maps supplied by the United States Department of Interior Geological Survey. Study sites were chosen based on abundance of woody vegetation. The strip-mining operation provided both north/south and east/west oriented water and slopes.

Bryophytes were collected in Crawford and Cherokee counties from August 1996 through December 1996. Additional collections were made between April 1997 and January 1998. Methods for collecting and processing specimens follow accepted bryological protocol. Information for each specimen collected included systematic numbering, date, approximate topographic location, and type of substrate. Voucher specimens were deposited in the Theodore M. Sperry Herbarium at Pittsburg State University and duplicates sent to other herbaria.

Field samples of mosses were identified by following the nomenclature of Anderson et al. (1990) except for Fissidentaceae which followed Pursell (1980). Taxonomic keys used in the identification process followed Conrad and Redfearn (1979), Crum and Anderson (1981), and Redfearn (1983, 1997). Liverwort samples were identified following the nomenclature of Timme and Redfearn (1997). Taxonomic keys used in the identification process followed Stotler and Crandall-Stotler (1977), Conrad and Redfearn (1979), Crum (1991), Hicks (1982, 1992), and Schuster (1992). State and county records for both mosses and liverworts were verified from bryological literature (Bowers and Honer 1992, Timme and Saliba 1992, Crosby 1994, Crosby and Magill 1997).

Sørenson's coefficient of community similarity index (CCs) was used to determine bryophyte diversity between communities (Mueller-Dombois and Ellenberg 1974, Zar 1996). Sørenson's coefficient of community similarity index assumes each species has an equal chance of occurring in a community. The equation uses the average number of species which can occur between the two communities and compares the theoretical with the actual number of species that do occur. Index values range from 0 to 1.0, where 0 is no species found in either community and a value of 1.0 where all species are found in both communities (Mueller-Dombois and Ellenberg 1974). Higher index values suggest species within those communities are more similar. Similarity indices were calculated for bryophytes collected from altered prairies (strip-mined land) and previous open tallgrass prairie studies.

Each prairie was assigned a number to simplify the comparison process within prairies. The prairie name and its corresponding number are:

1. La Petite Prairie, Southwest Missouri
2. West Missouri and Western Arkansas Prairie.
3. Prairie State Park, Barton County, Missouri
4. Southwest Missouri Prairie.
5. Konza Prairie, North central Kansas.
6. Freda Haffner Kettlehole Prairie, Northwest Iowa.
7. Goose Lake Prairie, Grundy County, Illinois.

Site Descriptions: Crawford County

Crawford County is located in southeast, Kansas on the southwestern edge of the Missouri border and encompasses approximately 233 square kilometers. Three study sites were surveyed in Crawford County.

Kansas Department of Wildlife and Parks obtained all study sites before 1972 (Brady 1998). These study sites were primarily mined for coal and clay.

Site 1.—Mined Land Wildlife Area Unit 1 is located T29S, R25E, Sec. 32 at latitude 37° 28' N and longitude 94° 42' W. This study site is approximately 145.8 ha. Examples of common woody plants growing on this study site include American elm (*Ulmus americana* L.), cottonwood (*Populus deltoides* Marsh.), hackberry (*Celtis occidentalis* L.), and Osage orange (*Maclura pomifera* (Raf.) Schneid.).

Mined Land Wildlife Area Unit 1 was mined by Patton Coal and Mining Company and Double F Coal Company from 1924 through 1927 (Brady 1998). Strip-mining of this area resulted in approximately 5 east/west and 8 north/south oriented bodies of water. Several small bodies of water (varying from approximately 6 m^2 to 180 m^2) exist throughout the study site.

Site 4.—Mined Land Wildlife Area Unit 4 is located T30S, R25E, Sec. 13 at a latitude of 37° 26' N and longitude 94° 37' W. This study site is approximately 129.6 ha. Common woody plants found on this study site include cottonwood, pin oak (*Quercus palustris* Muenchh.), slippery elm (*Ulmus rubra* Muhl.), and wild black cherry (*Prunus serotina* Ehrh.).

Mined Land Wildlife Area Unit 4 was mined by Reliance Coal and Mining Company from 1920 through 1924 (Brady 1998). Strip-mining of this area resulted in approximately 5 east/west and 5 north/south oriented bodies of water with several smaller bodies of water (varying at approximately 9 m^2) scattered throughout the study site.

Site 5.—Mined Land Wildlife Unit 5 is located T30S, R24E, Sec. 22 at a latitude of 37° 24' N and longitude 94° 46' W. This study site is approximately 64.8 ha. Common woody plants found on this study site include green ash (*Fraxinus pennsylvanica* (Vahl) Fern.) hackberry, pin oak, and slippery elm.

Mined Land Wildlife Area Unit 5 was mined by Walker Coal Company Number 1 in 1928 (Brady 1998). Strip-mining in this area resulted in approximately 3 east/west and 4 north/south oriented bodies of water with smaller bodies of water (varying from approximately 6 m^2 to 150 m^2) scattered throughout the study site.

Site Descriptions: Cherokee County

Cherokee County is located in southeast, Kansas on the southwestern edge of the Missouri border and south of Crawford County and encompasses approximately 231 km^2. Three study sites were surveyed in Cherokee County. These study sites were primarily mined for coal (Brady 1998).

Site 9.—Mined Land Wildlife Area Unit 9 is located T32S, R24E, Sec. 3 at latitude of 37° 17' N and longitude 94° 46' W. This study site is approximately 51.8 ha. Examples of common woody plants found growing on this study site include catalpa (*Catalpa speciosa*)Warder, honey locust (*Gleditsia triacanthos* L.), and pin oak.

Mined Land Wildlife Area Unit 9 was mined by Roy Millner Coal and Italiani Coal Company from 1914 through 1920 (Brady 1998). Strip-mining of the area resulted in 4 large linear pits along the perimeter of the study site. Very few areas of water were found on the interior of the study site.

Site 13.—Mined Land Wildlife Unit 13 is located T32S, R24E, Sec. 17 at latitude of 37° 15' N and longitude 94° 48' W. This study site is approximately 129.6 ha. Common woody plants growing in this study site include black walnut (*Juglans nigra* L.), burr oak (*Quercus macrocarpa* Michx.), pin oak, and wild black cherry.

Mined Land Wildlife Unit 13 was mined by the Crowe Coal Company from 1927 to 1930 (Brady 1998). Three bodies of water were positioned in an east/west orientation and 3 in a north/south orientation. Several smaller bodies of water (varying from approximately 6 m^2 to 100 m^2) were scattered throughout the study site. Steep slopes were found in the NW1/4 quadrant of this study site.

Site 19.—Mined Land Wildlife Area Unit 19 is located T32S, R23E, Sec. 9 at latitude of 37° 16' N and longitude 94° 54' W. Common woody plants found in this area include black walnut, cottonwood, and slippery elm.

Mined Land Wildlife Area Unit 19 was mined by the Pittsburg-Midway Coal Company Number 15 from 1937 through 1947 (Brady 1998). This study site was narrow with agricultural crops along the margins. Strip-mining of this area resulted in approximately 8 east/west and 6 north/south oriented bodies of water. Additional water pits were grouped together and not scattered throughout the study site.

RESULTS

Altered Prairies

Altogether, 555 bryophyte samples were collected from the 6 study sites. Results from moss samples indicated 71 species within 43 genera and 22 families (Appendix A). Results from liverwort samples indicated 8 species within 5 genera and 5 families (Appendix B). No hornworts were collected in either county.

Mosses collected and identified in Crawford County (Appendix D) included 42 species representing 28 genera within 18 families. Liverworts collected and identified (Appendix E) included 3 species among 2 genera within 2 families. Moss collections not previously reported in Crawford County included 23 species. These are *Amblystegium serpens* var. *juratzkanum, A. varium, Brachythecium salebrosum, Bryum dichotomum, Campylium chrysophyllum, Entodon cladorrhizans, E. compressus, Eurhynchium pulchellum, Fissidens obtusifolius, F. viridulus, Haplocladium virginianum, Hedwigia ciliata, Hypnum curvifolium, Leptodictyum riparium, Lindbergia brachyptera, Orthotrichum strangulatum, Plagiomnium ciliare, Platygyrium repens, Pohlia nutans, Rhizomnium punctatum, Sphagnum fimbriatum*, and *Tortula atherodes.*

Mosses collected and identified in Cherokee County (Appendix D) included 50 species representing 36 genera within 21 families. Liverworts collected and identified (Appendix E) included 8 species among 5 genera within 5 families. Moss collections not previously reported in Cherokee County included 32 new records. These are *Acaulon muticum, Amblystegium serpens, A. serpens* var. *juratzkanum, A. varium, Anomodon rostratus, Aulacomnium palustre, Brachythecium salebrosum, Bryum argenteum, B. dichotomum, B. lisae* var. *cuspidatum, Campylium chrysophyllum, Ceratodon* *purpureus, Entodon compressus, Fissidens bushii, F. minulutus, F. taxifolius, Haplocladium microphyllum, H. virginianum, Leptodictyum riparium, L. humile, Micromitrium austinii, Pogonatum brachyphyllum, Pylaisiella selwynii, Schistidium agassizii, S. apocarpum, Sphagnum cuspidatum, S. trinitense, S. lescurii, S. platyphyllum, Steerecleus serrulatum, Thelia hirtella,* and *Tortula plinthobia.*

Liverwort collections not previously reported in Crawford County included 1 addition to the county: *Frullania eboracensis*. Cherokee County had no new additions to the liverwort collection.

Five new additions to the moss flora of Kansas include *Sphagnum fimbriatum* collected in Crawford County and *Isopterygium tenerum, Micromitrium austinii*m, *Sphagnum platyphyllum*, and *Sphagnum lescurii* collected in Cherokee County.

Mosses not found in Crawford County but collected at Cherokee County study sites include, *Acaulon muticum, Bryum lisae* var. *cuspidatum, Eurhynchium hians, Fissidens bryoides, Leptodictyum humile, Micromitrium austinii, Pogonatum brachyphyllum, Pylaisiella selwynii, Schistidium apocarpum, Sphagnum lescurii, S. platyphyllum, Thelia hirtella,* and *Thuidium delicatulum.*

Mosses not found in Cherokee County but collected at Crawford County study sites include *Bryum argenteum, B. caespitum, Entodon cladorrhizans, Ephemerum crassinervium, Eurhynchium pulchellum, Fissidens obtusifolius, F. viridulus, Hedwigia ciliata, Hypnum curvifolium, Lindbergia brachyptera, Orthotrichum pumilum, Plagiomnium ciliare, Rhizomnium punctatum, Syntrichia pagorum,* and *Tortula atherodes.*

Rastorfer's (1981) bryophyte collection on strip-mined land in Grundy County, Illinois included 38 species, representing 27 genera within 14 families of mosses. Liverwort collections included 6 species among 6 genera within 6 families. Hornwort collections included 1 species.

Open Tallgrass Prairies

Bryophyte collections extracted from the literature for 7 open tallgrass prairies (Zales 1971; O'Keefe van der Linden and Farrar 1983; Timme 1983, 1987; Merrill 1991; Timme 1997) included 89 species of mosses within 46 genera and 21 families (Appendix C). Liverwort samples included 25 species among 14 genera within 10 families (Appendix F).

Bryophyte collections from La Petite Prairie, southwest Missouri (Timme 1983) included 9 species of mosses. No liverworts or hornworts were collected. Collections from several small prairies in western Missouri and western Arkansas (Timme 1987) included 21 species of mosses with no liverworts or hornworts collected. Collections from Prairie State Park, Barton County, Missouri included 32 species of mosses, 4 species of liverworts and 1 hornwort species. Collections from a small prairie in southwest Missouri (Timme 1997) included 29 species of mosses, 7 species of liverworts and 1 species of hornwort. Collections from the Konza Prairie in north central, Kansas (Merrill 1991), included 40 species of mosses and 4 species of liverworts. No hornworts were collected. Collections from Freda Haffner Kettlehole Prairie in northwest Iowa (O'Keefe van der Linden and Farrar 1983) included 30 species of mosses, 3 species of liverworts and 1 species of hornwort. Collections from Goose Lake Prairie in Grundy County Illinois (Zales 1971) included 22 species of mosses, 6 species of liverworts and 1 species of hornwort.

Calculation of Community Similarity

Mean results of the CCs index for the mosses within Crawford County were 0.807 (family), 0.683 (genus), and 0.485 (species) level. Results of the CCs index for the mosses within Cherokee County were 0.664 (family), 0.609 (genus), and 0.441 (species) level (Table 1). Results of the CCs index for the mosses between both counties were 0.792 (family), 0.647 (genus), and 0.504 (species) level (Table 2).

Mean results of the CCs index for the liverworts within Crawford County were 0.889 (family), 0.778 (genus), and 0.771 (species) level. Results of the CCs index for the liverworts within Cherokee County were 0.600 (family), 0.600 (genus), and 0.600 (species) level (Table 3). Results of the CCs index for the liverworts between both counties were 0.756 (family), 0.756 (genus), and 0.689 (species) level (Table 4).

The combined mean for the moss community similarity index for both counties at the family level was 0.700, genus level, 0.647 and species level, 0.488. The combined mean for the liverwort community similarity index for both counties at the family level was 0.751, the genus level was 0.729, and the species level was 0.676 (Table 5).

Sørenson's coefficient of community similarity index was calculated for mosses at the family (Appendix G), genus, and species level (Appendix H) between each of the 7 open tallgrass prairies. Means for the CCs index at the family level were 0.660, genus level, 0.486 and species level, 0.319 (Table 6). The CCs index was also calculated for liverworts at

Table 1. Sørenson's coefficient of similarity of mosses within each study site.

CRAWFORD COUNTY

Comparison between study sites	Family	Genus	Species
1 and 4	0.765	0.667	0.471
1 and 5	0.857	0.683	0.424
4 and 5	0.800	0.700	0.560
MEAN	0.807	0.683	0.485

CHEROKEE COUNTY

Comparison between study sites	Family	Genus	Species
9 and 13	0.667	0.565	0.448
9 and 19	0.615	0.595	0.409
13 and 19	0.710	0.667	0.467
MEAN	0.664	0.609	0.441

Table 2. Sørenson's coefficient of similarity of mosses between study sites of both counties.

Comparison between study sites	Family	Genus	Species
1 and 9	0.786	0.718	0.549
1 and 13	0.848	0.653	0.507
1 and 19	0.846	0.650	0.415
4 and 9	0.667	0.684	0.511
4 and 13	0.857	0.625	0.540
4 and 19	0.714	0.615	0.449
5 and 9	0.857	0.684	0.533
5 and 13	0.788	0.583	0.525
5 and 19	0.769	0.615	0.511
MEAN	0.792	0.647	0.504

Table 3. Sørenson's coefficient of similarity of liverworts within each study site.

CRAWFORD COUNTY

Comparison between study sites	Family	Genus	Species
1 and 4	0.667	0.667	0.800
1 and 5	1.000	1.000	0.667
4 and 5	1.000	0.667	0.667
MEAN	0.889	0.778	0.711

CHEROKEE COUNTY

Comparison between study sites	Family	Genus	Species
9 and 13	0.400	0.400	0.400
9 and 19	1.000	1.000	1.000
13 and 19	0.400	0.400	0.400
MEAN	0.600	0.600	0.600

Table 4. Sørenson's coefficient of similarity of liverworts between study sites of both counties.

Comparison between study sites	Family	Genus	Species
1 and 9	1.000	1.000	1.000
1 and 13	0.400	0.400	0.500
1 and 19	1.000	1.000	1.000
4 and 9	0.667	0.667	0.800
4 and 13	0.667	0.667	0.546
4 and 19	0.667	0.667	0.800
5 and 9	1.000	1.000	0.667
5 and 13	0.400	0.400	0.222
5 and 19	1.000	1.000	0.667
Mean	0.756	0.756	0.689

Table 5. Sørenson's coefficient of similarity mean for both counties.

Plant	Family	Genus	Species
Mosses	0.770	0.647	0.488
Liverworts	0.751	0.729	0.676

Table 6. Sørenson's coefficient of similarity of mosses on 7 open tallgrass prairies.

Comparison between study sites	Family	Genus	Species
1 and 2	0.600	0.615	0.333
1 and 3	0.667	0.457	0.244
1 and 4	0.500	0.483	0.263
1 and 5	0.667	0.343	0.204
1 and 6	0.800	0.429	0.211
1 and 7	0.667	0.276	0.258
2 and 3	0.667	0.571	0.377
2 and 4	0.667	0.486	0.440
2 and 5	0.667	0.465	0.197
2 and 6	0.571	0.389	0.160
2 and 7	0.583	0.378	0.370
3 and 4	0.774	0.696	0.426
3 and 5	0.640	0.429	0.389
3 and 6	0.636	0.578	0.295
3 and 7	0.800	0.609	0.370
4 and 5	0.643	0.435	0.290
4 and 6	0.560	0.462	0.310
4 and 7	0.643	0.500	0.353
5 and 6	0.842	0.667	0.406
5 and 7	0.636	0.478	0.406
6 and 7	0.632	0.462	0.392
MEAN	0.660	0.486	0.319

the family (Appendix G), genus and species level (Appendix H). Means for the CCs index at the family level were 0.440, genus level, 0.354 and species level, 0.107 (Table 7).

A comparison was made between the means of the CCs index for both the mosses and liverworts of the seven open tallgrass and six altered prairies (Table 8). Mean CCs index for the mosses on the tallgrass prairie were 0.660 (family), 0.486 (genus), and 0.319 (species) level. Mean CCs index for liverworts on the tallgrass prairie were 0.440 (family), 0.354 (genus), and 0.107 (species) level. Mean CCs index

Table 7. Sørenson's coefficient of similarity of liverworts on seven open tallgrass prairies.

Comparison between study sites	Family	Genus	Species
3 and 4	0.546	0.500	0.333
3 and 5	0.333	0.333	0.000
3 and 6	0.667	0.286	0.000
3 and 7	0.667	0.400	0.200
4 and 5	0.222	0.200	0.000
4 and 6	0.222	0.200	0.000
4 and 7	0.667	0.428	0.100
5 and 6	0.500	0.500	0.000
5 and 7	0.286	0.250	0.000
6 and 7	0.286	0.444	0.444
MEAN	0.440	0.354	0.107

Table 8. Sørenson's coefficient of similarity between open tallgrass prairies and prairies altered by strip-mining.

	Family	Genus	Species
Mosses			
Tallgrass Prairie	0.660	0.486	0.319
Altered Prairie	0.770	0.647	0.488
Liverworts			
Tallgrass Prairie	0.440	0.354	0.107
Altered Prairie	0.751	0.729	0.676

for the mosses on the altered prairie were 0.770 (family), 0.647 (genus), and 0.488 (species) level. Mean CCs index for the mosses on the liverworts on the altered prairie were 0.751 (family), 0.729 (genus), and 0.676 (species) level.

DISCUSSION

The goal of this study was to collect and identify bryophytes in as many habitats within the altered prairie (mined land) as possible. All study sites were similar in habitat. The north/south and east/west facing slopes were abundant on each study site and all supported several regions of water of varying sizes.

Average temperatures between Crawford and Cherokee counties in 1996 and 1997 ranged from –21.7°C to 35.3°C and annual precipitation ranged from 105.44 cm to 119.96 cm. Temperature and precipitation were conducive to bryophyte growth during the collecting period.

Burton's study (1990) used both terrestrial and aquatic bryophytes (*Bryum argenteum, Ceratodon purpureus, Tortula muralis, Hypum cupressiforme, Brachythecium* spp., *Sphagnum fimbriatum* and *Fontinalis* ssp.) to monitor heavy metal contamination in mining areas and along roadsides. Five out of the 7 species in Burton's study were found on 1 or more of the Crawford and Cherokee County study sites, with the exception of *Tortula muralis* and *Fontinalis* ssp.

Sørenson's coefficient of community similarity index for mosses within each study site suggested the communities at the family level were more similar than at the genus and species level. Mosses in Crawford County had a higher similarity index at the family level than Cherokee County but at the genus and species level the coefficient indices were lower suggesting the communities were dissimilar.

Sørenson's coefficient of community similarity index for liverworts within each study site suggested the communities at the family, genus and species level for each county were more similar than dissimilar. Liverwort collections in Crawford County had a much higher similarity indices than Cherokee County suggesting the communities between counties were more dissimilar than similar.

Rastorfer's mined land study (1981) had similar taxa at the family, genus, and species level as the southeast Kansas study. This suggests that it is possibly the habitat and not the organism that dictates where it will grow.

Sørenson's coefficient of community similarity index was used to measure bryophyte diversity between altered prairies (strip-mined land) and open tallgrass prairies. When combining all taxa for both mosses and liverworts collected on the open tallgrass prairie (114 taxa), there was a greater number of species reported than species collected on the altered prairie (71 taxa). In this study, the species number and similarity index for the altered prairies (71 taxa, 0.488 CCs, respectively) compared to the open tallgrass prairies (114 taxa, 0.319 CCs, respectively) were both low, suggesting the diversity is neither high nor low. However the open tallgrass prairie had a high species number (114 taxa) and low similarity index (0.319 CCs) suggesting a greater diversity. If the taxa number is high and the similarity index is low the community has a greater diversity of bryophytes. The results of this study do not indicate a higher diversity of bryophytes growing on altered prairies than open tallgrass prairies. However, they do suggest the open tallgrass prairie and the altered prairie may be separate and unique habitats with only minimal overlap in species.

CONCLUSION

This study suggested bryophyte diversity is not greater on altered prairies (mined land) than on open tallgrass prairies. It has contributed to documenting the bryoflora of Crawford and Cherokee counties, Kansas. New bryoflora was reported for both counties. Crawford County resulted in 25 new additions and Cherokee County 33 new additions. Also, *Isopterygium tenerum* (Sw.) Mitt, *Micromitrium austinii* Aust., *Sphagnum fimbriatum* Wils. *ex* Wils. & Hook. *f. in* Hook., *Sphagnum lescurii* Sull *in* Gray, and *Sphagnum platyphyllum* (Lindb. *ex* Braithw.) *ex* Warnst. represented 5 new state records for Kansas. After a number of visits to each study site, the possibility still remains that not all species have been collected. Further collecting is needed to monitor the bryophyte population in southeast Kansas.

Previous studies (Whitehead and Brooks 1969, Burton 1990, Martinez-Abaigar et al. 1993) have shown that certain species of bryophytes can be used as environmental indicators. Whitehead and Brooks (1969) used aquatic bryophytes to locate uranium minerals in streams. Both terrestrial and aquatic bryophytes, *Bryum argenteum* Hedw., *Ceratodon purpureus* (Hedw.) Brid., *Tortula muralis* Hedw., *Hypum cupressiforme* Hedw., *Brachythecium* spp. Schimp. in B.S.G., *Sphagnum fimbriatum* Wils. *ex* Wils. & Hook., and *Fontinalis* spp. Hedw. have been used to monitor heavy metal contamination in mining areas and along roadsides (Burton 1990). All of these bryophytes have been found in this study with the exception of *Tortula muralis* Hedw., and *Fontinalis* spp. Hedw. Using the information obtained in this study, a future investigation could be conducted using bryophytes as environmental indicators to determine or monitor specific environmental pollutants such as metals or chemicals found in soil or water in and around the strip-mined areas. Perhaps by using bryophyte growth as an indicator it can be determine what affects these pollutants have on the altered prairies in southeast Kansas.

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Appendix A. Complete list of mosses collected in Crawford and Cherokee counties, Kansas (collection number included.)

Species	Collection Number
Acaulon muticum (Hedw.) C. Muell.	(Cherokee B-235)
Amblystegium serpens var. *juratzkanum* (Schimp.) Rau & Herv.	(Crawford B-123; Cherokee B-191)
Amblystegium serpens (Hedw.) Schimp. *in* B.S.G.	(Crawford B-127; Cherokee B-207)
Amblystegium varium (Hedw.) Lindb.	(Crawford B-13; Cherokee B-370c)
Anomodon rostratus (Hedw.) Schimp.	(Cherokee B-372)
Atrichum angustatum (Brid.) Bruch & Schimp. *in* B.S.G.	(Crawford B-18; Cherokee B-64c)
Aulacomnium palustre (Hedw.) Schwaegr.	(Crawford B-160; Cherokee B-34a)
Barbula unguiculata Hedw.	(Cherokee B-91b)
Brachythecium acuminatum (Hedw.) Rau & Herv.	(Crawford B-49)
Brachythecium oxycladon (Brid.) Jaeg & Sauerb.	(Crawford B-52; Cherokee B-84)
Brachythecium salebrosum (Web. & Mohr) B.S.G.	(Crawford B-51)
Bryum argenteum Hedw.	(Cherokee B-114a)
Bryum dichotomum Hedw.	(Cherokee B-119b)
Bryum caespiticium Hedw.	(Crawford B-387)
Bryum lisae var. *cuspidatum* (Bruch & Schimp. *in* B.S.G.)	(Cherokee B-80b)
Campylium chrysophyllum (Brid.) J. Lange.	(Crawford B-155; Cherokee B-237a)
Campylium hispidulum (Brid.) Mitt.	(Crawford B-381b; Cherokee B-32a)
Ceratodon purpureus (Hedw.) Brid.	(Cherokee B-315a)
Ditrichum pallidum (Hedw.) Hampe.	(Crawford B-3; Cherokee B-236)
Entodon cladorrhizans (Hedw.) C. Muell.	(Crawford B-132; Cherokee B-4)
Entodon compressus C. Muell.	(Crawford B-6b)
Entodon seductrix (Hedw.) C. Muell.	(Crawford B-4; Cherokee 37)
Ephemerum crassinervium (Schwaegr.) Hampe	(Crawford B-153b)
Eurhynchium hians (Hedw.) Sande-Lac.	(Cherokee B-181)
Eurhynchium pulchellum (Hedw.) Jenn.	(Crawford B-416)
Fissidens bryoides (Hedw.)	(Crawford B-2b; Cherokee B-179b)
Fissidens bushii (Card. & Thér)	(Cherokee B-186b)
Fissidens fontanus (B. Pyl.) Steud.	(Crawford B-399b)
Fissidens obtusifolius Wils.	(Crawford B-275a)
Fissidens minutulus Sull.	(Cherokee B-370a)
Fissidens taxifolius (Hedw.)	(Crawford B-53a; Cherokee B-106)
Fissidens viridulus (Web. & Mohr) Wahlenb.	(Crawford B-380)
Funaria sp. Hedw.	(Crawford B-153a)

Appendix A (Continued)

Haplocladium microphyllum (Hedw.) Broth.	(Crawford B-46; Cherokee B-74a)
Haplocladium virginianum (Brid.) Wat. & Iwats.	(Crawford B-6a; Cherokee B-67)
Hedwigia ciliata (Hedw.) P. Beauv.	(Crawford B-14)
Homomallium adnatum (Hedw.) Broth.	(Cherokee B-225)
Hypnum curvifolium (Hedw.)	(Crawford B-386a)
Isopterygium tenerum (Sw.) Mitt.	(Cherokee B-36b)
Leptodictyum riparium (Hedw.) Warnst.	(Crawford B-21; Cherokee B-32b)
Leptodictyum humile (P.Beauv.) Ochyra.	(Cherokee B-105)
Leskea gracilescens Hedw.	(Crawford B-22; Cherokee B-40)
Leucodon julaceus (Hedw.) Sull.	(Crawford B-176; Cherokee B-94a)
Lindbergia brachyptera (Mitt.) Kindb.	(Crawford B-19)
Micromitrium austinii Aust.	(Cherokee B-290)
Orthotrichum pumilum Sw.	(Crawford B-175a; Cherokee B-208c)
Orthotrichum pusillum Mitt.	(Crawford B-20; Cherokee B-194a)
Orthotrichum strangulatum P. Beauv.	(Crawford B-272)
Philonotis sp. Brid.	(Cherokee B-295a)
Physcomitrium pyriforme (Brid.) Hampe	(Cherokee B-188b)
Plagiomnium ciliare (C. Müll.)	(Crawford B-140)
Plagiomnium cuspidatum (Hedw.) T. Kop.	(Crawford B-5; Cherokee B-30)
Platygyrium repens (Brid.) Schimp. *in* B.S.G.	(Crawford B-10; Cherokee B-134)
Pogonatum brachyphyllum (Michx.) P. Beauv.	(Crawford B-305)
Pohlia nutans (Hedw.) Lindb.	(Crawford B-148b; Cherokee B-114b)
Pylaisiella selwynii (Kindb.) Crumetal.	(Cherokee B-94b)
Rhizomnium punctatum (Hedw.) T. Kop.	(Crawford B-123a)
Schistidium agassizii Sull. & Lesq. *in* Sull.	(Cherokee B-212)
Schistidium apocarpum (Hedw.) Bruch. & schimp. *in* B.S.G.	(Cherokee B-226)
Sphagnum cuspidatum Ehrh. *ex* Hoffm.	(Cherokee B-26b)
Sphagnum fimbriatum Wils. *ex* Wils. & Hook. *f. in* Hook.	(Crawford B-165)
Sphagnum lescurii Sull. *in* Gray	(Crawford B-163; Cherokee B-26a)
Sphagnum platyphyllum (Lindb. *ex* Braithw.) *ex* Warnst.	(Cherokee B-29b)
Sphagnum trinitense C. Muell.	(Cherokee B-28)
Steerecleus serrulatum (Hedw.) Robins.	(Crawford B-2a; Cherokee B-64b)
Syntrichia pagorum (Milde) Amann	(Crawford B-48c)
Thelia hirtella (Hedw.) Sull. *in* Sull. & Lesq.	(Cherokee B-241)
Thuidium delicatulum (Hedw.) Schimp. *in* B.S.G.	(Cherokee B-68)
Tortula atherodes Zand.	(Crawford B-152)
Tortula plinthobia (Sull.& Lesq.) Sull.	(Cherokee B-113c)
Weissia controversa Hedw.	(Crawford B-59b; Cherokee B-25)

Appendix B. Complete list of liverworts collected in Crawford and Cherokee counties, Kansas (collection number included.)

Species	Collection Number
Calypogeia muelleriana (Schiffn.)	(Cherokee B-293a)
Cephaloziella rubella (Nees) Warnst.	(Cherokee B-293b)
Chiloscyphus profundus (Nees) Eng. & Schust.	(Crawford B-157; Cherokee B-35b)
Frullania eboracensis Gott.	(Crawford B-379a; Cherokee B-65)
Frullania inflata Gott.	(Crawford B-1; Cherokee B-83b)
Riccia hirta (Aust.) Underw.	(Cherokee B-431)
Riccia sorocarpa Bisch.	(Cherokee B-323)
Riccia spp. L.	(Cherokee B-304)

Appendix C. Alphabetical list of mosses from the literature of 7 open tallgrass prairies.

Amblystegium serpens (Hedw.)
Amblystegium varium (Hedw.)
Amblystegium varium var. varium (Hedw.) Lindb.
Anomodon rostratus (Hedw.)
Astomum muhluenbergianum (Sw.)
Astomum phascoides (Hook. ex Drumm.)
Atrichum angustatum (Brid.)
Aulacomnium palustre (Hedw.)
Barbula convoluta Hedw.
Barbula unguiculata Hedw.
Brachythecium acuminatum (Hedw.) Aust.
Brachythecium crytophyllum (Kindb.) Redf. ex Crum
Brachythecium oxycladon (Brid.) Jaeg.
Brachythecium rutabulum (Hedw.)
Brachythecium salebrosum (Web. & Mohr) Schimp in B.S.G.
Brachythecium sp.
Bruchia flexuosa (Sw. ex Schawegr.)
Bruchia sullvantii Aust.
Bryoandersonia illecebra (Hedw.) Robins.
Bryum algovicum Sendt. ex C. Müll.
Bryum argenteum Hedw.
Bryum caespiticium Hedw.
Bryum capillare Hedw.
Bryum creberrimum Taylor
Bryum dichotomum Hedw.
Bryum klinggraeffii Schimp in Klinggr.
Bryum lisae var. cuspidatum (Bruch&Schimp. in B.S.G.) Marg.
Bryum pseudotriquetrum (Hedw.) Gaertn. et al.
Campylium chrysophyllum (Brid.) J. Lange.
Campylium hispidulum (Brid.) Mitt.
Ceratodon purpureus var. purpureus (Hedw.) Brid.
Clasmatodon parvulus (Hampe)
Cratoneuron filicinum (Hedw.) Spruce
Desmatodon obtusifolius (Schwaegr.) Schimp.
Desmatodon tophaceus (Brid.) Jur. ex Whiteh.
Dicranella heteromalla (Hedw.) Schimp.
Didymodon fallax (Hedw.) Zand.
Ditrichum pallidum (Hedw.) Hampe
Drepanocladus aduncus (Hedw.) Warnst.
Drepanocladus vernicosus (Mitt.) Warnst.
Entodon seductrix (Hedw.) C. Müll.
Ephemerum cohaerens (Hedw.) Hampe.
Ephemerum crassinervium (Schawegr.) Hampe.
Ephemerum spinulosum Bruch & Schimp. in Schimp.
Eurhynchium hians (Hedw.) Sande-Lac.
Eurhynchium pulchellum (Hedw.) Jenn.
Fissidens bryoides Hedw.
Fissidens bushii (Card. & Thér)
Fissidens cristatus Wils. ex Mitt.
Fissidens dubius P. Beauv.
Fissidens kansanus Ren. & Card.
Fissidens obtusifolius Wils.
Fissidens taxifolius Hedw.
Fontinalis duriaei Schimp.
Fontinalis novae-angliae Sull.
Funaria flavicans Michx.
Funaria hygrometrica Hedw.
Grimmia pulvinata (Hedw.) Sm.
Haplocladium microphyllum (Hedw.)
Homomallium adnatum (Hedw.) Broth.
Homomallium mexicanum Card.
Hygroamblystegium tenax var. tenax (Hedw.)
Leptobryum pyriforme (Hedw.) Wils.
Leptodictyum laxirete (Card. & Thér) Broth.
Leptodictyum riparium (Hedw.) Warnst.
Leptodictyum trichopodium (Schultz)
Phascum cuspidatum Hedw.
Physcomitrium hookeri Hampe
Physcomitrium pyriforme (Hedw.) Hampe
Plagiomnium cuspidatum (Hedw.) T. Kop
Platygyrium repens (Brid.) Schimp. in B.S.G.
Pleuridium subulatum (Hedw.) Rabenh.
Pleuridium sullivantii Aust.
Pogonatum pensilvanicum (Hedw.) P. Beauv.
Pohlia nutans (Hedw.) Lindb.
Pohlia wahlenbergii (Web. & Mohr) Andrews
Polytrichum commune Hedw.
Pottia davilliana (Sm. in Drake) C. Jens.
Ptychomitrium incurvum (Schwaegr.) Spruce
Sphagnum compactum DC in Lam. & DC.
Sphagnum contortum Schultz
Sphagnum cuspidatum Ehrh. Ex Hoffm.
Sphagnum fallax (Klinggr.) Klinggr.
Sphagnum trinitense C. Müll.
Steercleus delicatulum Jam. in Sull.
Steercleus serrulatus (Hedw.) Robins.
Taxiphyllum taxirameum (Mitt.) Fleisch.
Thuidium delicatulum (Hedw.) Schimp. in B.S.G.
Weissia controversa Hedw.

Appendix D. Alphabetical listing of moss taxa by study site.

Crawford County—Site 1

Amblystegiaceae
- Amblystegium serpens
- Amblystegium varium
- Campylium chrysophyllum
- Campylium hispidulum
- Leptodictyum riparium

Aulacomniaceae
- Aulacomnium palustre

Brachytheciaceae
- Brachythecium acuminatum

Crawford County—Site 1 (Continued)
- Brachythecium oxycladon
- Brachythecium salebrosum
- Eurhynchium pulchellum
- Steerecleus serrulatus

Bryaceae
- Bryum caespiticium

Ditrichaceae
- Ditrichum pallidum

Entodontaceae
- Entodon seductrix

Appendix D (Continued)

Crawford County—Site 1 (Continued)

Fissidentaceae
- Fissidens fontanus
- Fissidens obtusifolius
- Fissidens taxifolius
- Fissidens viridulus

Hypnaceae
- Hypnum curvifolium
- Platygyrium repens

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Leskeaceae
- Haplocladium microphyllum
- Haplocladium virginianum
- Leskea gracilescens

Leucodontaceae
- Leucodon julaceus

Mniaceae
- Plagiomnium cuspidatum

Orthotrichaceae
- Orthotrichum pusillum
- Orthotrichum strangulatum

Polytrichaceae
- Atrichum angustatum

Pottiaceae
- Syntrichia pagorum
- Weissia controversa

Crawford County—Site 4

Amblystegiaceae
- Amblystegium serpens
- Amblystegium varium
- Campylium chrysophyllum
- Leptodictyum riparium

Aulacomniaceae
- Aulacomnium palustre

Brachytheciaceae
- Steerecleus serrulatus

Bryaceae
- Bryum dichotomum

Ditrichaceae
- Ditrichum pallidum

Entodontaceae
- Entodon compressus
- Entodon seductrix

Ephemeraceae
- Ephemerum crassinervium

Fissidentaceae
- Fissidens bryoides

Hedwigiaceae
- Hedwigia ciliata

Hypnaceae
- Platygyrium repens

Crawford County—Site 4 (Continued)

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Leskeaceae
- Haplocladium microphyllum
- Haplocladium virginianum
- Leskea gracilescens
- Lindbergia brachyptera

Leucodontaceae
- Leucodon julaceus

Lophocoleaceae
- Chiloscyphus profundus

Mniaceae
- Plagiomnium cuspidatum

Orthotrichaceae
- Orthotrichum pumilum
- Orthotrichum pusillum

Polytrichaceae
- Atrichum angustatum

Sphagnaceae
- Sphagnum trinitense
- Sphagnum fimbriatum
- Sphagnum lescurii

Crawford County—Site 5

Amblystegiaceae
- Amblystegium serpens
- Amblystegium serpens var. juratzkanum
- Amblystegium varium
- Leptodictyum riparium

Brachytheciaceae
- Brachythecium oxycladon
- Steerecleus serrulatus

Bryaceae
- Bryum dichotomum
- Pohlia nutans

Ditrichaceae
- Ditrichum pallidum

Entodontaceae
- Entodon cladorrhizans
- Entodon seductrix

Ephemeraceae
- Ephemerum crassinervium

Fissidentaceae
- Fissidens taxifolius

Funariaceae
- Funaria sp.

Hypnaceae
- Platygyrium repens

Jubulaceae
- Frullania inflata

Leskeaceae
- Haplocladium microphyllum
- Leskea gracilescens

Appendix D (Continued)

Crawford County—Site 5 (Continued)

Leucodontaceae
- Leucodon julaceus

Mniaceae
- Plagiomnium ciliare
- Plagiomnium cuspidatum
- Rhizomnium punctatum

Polytrichaceae
- Atrichum angustatum

Pottiaceae
- Phascum cuspidatum
- Weissia controversa

Cherokee County—Site 9

Amblystegiaceae
- Amblystegium serpens
- Amblystegium serpens var. juratzkanum
- Campylium chrysophyllum
- Leptodictyum humile
- Leptodictyum riparium

Brachytheciaceae
- Brachythecium salebrosum
- Steerecleus serrulatus

Bryaceae
- Bryum lisae var. cuspidatum

Ditrichaceae
- Ditrichum pallidum

Entodontaceae
- Entodon seductrix

Fissidentaceae
- Fissidens taxifolius

Funariaceae
- Physcomitrium pyriforme

Hypnaceae
- Platygyrium repens

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Leskeaceae
- Haplocladium microphyllum
- Haplocladium virginianum
- Leskea gracilescens

Mniaceae
- Plagiomnium cuspidatum

Polytrichaceae
- Atrichum angustatum

Pottiaceae
- Acaulon muticum

Theliaceae
- Thelia hirtella

Thuidiaceae
- Thuidium delicatulum

Cherokee County—Site 13

Amblystegiaceae
- Amblystegium serpens
- Amblystegium serpens var. juratzkanum
- Amblystegium varium
- Campylium chrysophyllum
- Campylium hispidulum
- Leptodictyum riparium

Aulacomniaceae
- Aulacomnium palustre

Bartramiaceae
- Philonotis sp.

Brachytheciaceae
- Brachythecium oxycladon
- Eurhynchium hians
- Steerecleus serrulatus

Bryaceae
- Pohlia nutans
- Calypogeiaceae
- Calypogeia muelleriana
- Cephaloziella
- Cephaloziella rubella

Ditrichaceae
- Ditrichum pallidum
- Ceratodon purpureus

Entodontaceae
- Entodon seductrix

Ephemeraceae
- Micromitrium austinii

Fissidentaceae
- Fissidens bryoides
- Fissidens bushii
- Fissidens minutulus
- Fissidens taxifolius

Funariaceae
- Physcomitrium pyriforme

Hypnaceae
- Homomallium adnatum
- Isopterygium tenerum
- Pylaisiella selwynii

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Leskeaceae
- Haplocladium microphyllum
- Leskea gracilescens

Leucodontaceae
- Leucodon julaceus

Lophocoleaceae
- Chiloscyphus profundus

Mniaceae
- Plagiomnium cuspidatum

Appendix D (Continued)

Cherokee County—Site 13 (Continued)

Orthotrichaceae
- Orthotrichum pusillum

Polytrichaceae
- Atrichum angustatum
- Pogonatum brachyphyllum

Pottiaceae
- Weissia controversa

Ricciaceae
- Riccia hirta
- Riccia sorocarpa
- Riccia sp.

Sphagnaceae
- Sphagnum cuspidatum
- Sphagnum lescurii
- Sphagnum platyphyllum
- Sphagnum trinitense

Thuidiaceae
- Anomodon rostratus

Cherokee County—Site 19

Amblystegiaceae
- Amblystegium serpens
- Campylium hispidulum
- Leptodictyum humile
- Leptodictyum riparium

Brachytheciaceae
- Brachythecium oxycladon
- Steerecleus serrulatus

Bryaceae
- Bryum argenteum

Cherokee County—Site 19 (Continued)

Bryaceae (Continued)
- Bryum dichotomum
- Pohlia nutans

Entodontaceae
- Entodon compressus
- Entodon seductrix

Fissidentaceae
- Fissidens taxifolius

Grimmiaceae
- Schistidium agassizii
- Schistidium apocarpum

Hypnaceae
- Homomallium adnatum
- Pylaisiella selwynii

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Leskeaceae
- Haplocladium microphyllum
- Leskea gracilescens
- Leucodontaceae
- Leucodon julaceus

Mniaceae
- Plagiomnium cuspidatum
- Orthotrichaceae
- Orthotrichum pumilum

Pottiaceae
- Barbula unguiculata
- Tortula plinthobia

Appendix E. Alphabetical list of liverwort taxa by study site.

Crawford County—Site 1

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Crawford County—Site 4

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Lophocoleaceae
- Chiloscyphus profundus

Crawford County—Site 5

Jubulaceae
- Frullania inflata

Cherokee County—Site 9

Jubulaceae
- Frullania eboracensis

Cherokee County—Site 13

Calypogeiaceae
- Calypogeia muelleriana

Cephaloziaceae
- Cephaloziella rubella

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Lophocoleaceae
- Chiloscyphus profundus

Ricciaceae
- Riccia hirta
- Riccia sorocarpa
- Riccia sp.

Cherokee County—Site 19

Jubulaceae
- Frullania eboracensis
- Frullania inflata

Appendix F. Alphabetical list of liverworts (from literature) of 7 open tallgrass prairies.

Asterella tenella (L.) Beauv.
Cephalozia connivens (Dicks.) Lindb.
Cephalozia lunulifolia (Dum.) Dum.
Cephaloziella hampeana (Nees) Schiff.
Chiloscyphus profundus (Nees) Eng. & Schust.
Fossombronia brasiliensis Steph.
Fossombronia foveolata Lindb.
Jamesoniella autumnalis (DeCand.) Steph.
Lophocolea heterophylla (L.)
Mannia fragrans (Balbis) Frye & Clark
Oxymitra paleacea (Bisch.)
Riccardia pinguis (L.)
Riccia austinii Steph.
Riccia beyrichiana Hampe ex Lehm.
Riccia campbelliana Howe
Riccia dictyospora Howe
Riccia fluitans L.
Riccia frostii Aust.
Riccia hirta (Aust.) Underw.
Riccia lamellosa Raddi
Riccia sorocarpa Bisch.
Ricciocarpus nutans (L.) Corda
Solenostoma gracillimum (Sm.) Schust.
Sphaerocarpus michelii Bellardi
Sphaerocarpus texanus Aust.

Appendix G. Alphabetical list of bryoflora families of the 7 open tallgrass prairies and 6 altered prairies (mined land).

Tallgrass Prairies	Altered Prairies
Mosses	
Amblystegiaceae	Amblystegiaceae
Aulacomniaceae	Aulacomniaceae
Brachytheciaceae	Bartramiaceae
Bruchiaceae	Brachytheciaceae
Bryaceae	Bryaceae
Dicranaceae	Ditrichaceae
Ditrichaceae	Entodontaceae
Entodontaceae	Ephemeraceae
Ephemeraceae	Funariaceae
Fabroniaceae	Fissidentaceae
Fissidentaceae	Grimmiaceae
Fontinalaceae	Hedwigiaceae
Funariaceae	Hypnaceae
Grimmiaceae	Leskeaceae
Hypnaceae	Leucodontaceae
Mniaceae	Mniaceae
Polytrichaceae	Orthotrichaceae
Pottiaceae	Polytrichaceae
Ptychomitriaceae	Pottiaceae
Sphagnaceae	Sphagnaceae
Thuidiaceae	Theliaceae
	Thuidiaceae
Liverworts	
Aytoniaceae	Calypogeiaceae
Cephaloziaceae	Cephaloziellaceae
Cephaloziellaceae	Lophocoleaceae
Codoniaceae	Jubulaceae
Jungermanniaceae	Ricciaceae
Lophocoleaceae	
Oxymitraceae	
Ricciaceae	
Riccardiaceae	
Sphaerocarpaceae	

Appendix H. Moss and liverwort taxa collected from the 7 open tallgrass prairies at the genus and species level. (x = **genus**, s = *species*; xs = if there is only 1 species in a genus). 1= La Petite Prairie, Southwest Missouri, 2= West Missouri and Western Arkansas Prairie, 3= Prairie State Park, Southwest Missouri, 4= Southwest Missouri Prairie, 5= Konza Prairie, North central Kansas, 6= Freda Haffner Kettlehole Prairie, Northwest Iowa, 7= Goose Lake Prairie, Grundy County Illinois.

Taxa	1	2	3	4	5	6	7
MOSSES							
Amblystegium		x	x		x	x	x
A. varium		s			s	s	s
A. serpens			s		s		
A. varium var. *varium*			s				
Anomodon rostratus					xs		
Astomum			x		x	x	
A. muhluenbergianum			s		s	s	
A. phascoides					s		
Atrichum angustatum	xs	xs	xs	xs			xs
Aulacomnium palustre		xs	xs	xs			xs
Barbula			x	x	x	x	
B. unguiculata			s	s	s		
B. convoluta						s	
Brachythecium	x	x	x		x	x	
B. oxycladon	s	s	s		s		
B. rutabulum		s	s				
B. acuminatum					s		
B. cyrtophyllum					s		
B. salebrosum					s	s	
Brachythecium spp.						s	
Bruchia			x				x
B. flexuosa			s				
B. sullvantii							s
Bryoandersonia illecebra	xs	xs					
Bryum	x	x	x	x	x	x	x
B. pseudotriquetrum	s	s	s	s	s	s	s
B caespiticium		s		s	s	s	s
B. capillare		s					
B. argenteum			s		s	s	
B. dichotomum			s				
B. lisae var. *cuspidatum*			s	s			
B. creberrimum						s	
B. algovicum						s	
B. klinggraeffii						s	
Campylium	x	x	x	x	x	x	
C. hispidulum	s			s	s	s	
C. chrysophyllum		s	s	s	s	s	
Ceratodon purpureus purpureus			xs	xs		xs	xs
Clasmatodon parvulus		xs					
Cratoneuron filicinum							xs
Desmatodon					x	x	x
D. tophaceus					s		
D. obtusifolius						s	s
Dicranella heteromalla		xs	xs	xs			
Didymodon fallax						xs	
Ditrichum pallidum	xs	xs	xs	xs			xs

Appendix H (Continued)

Taxa	1	2	3	4	5	6	7
Drepanocladus					x		x
D. aduncus					s		s
D. vernicosus					s		
Entodon seductrix		xs		xs			
Ephemerum		x		x		x	
E. crassinervium		s		s			
E. cohaerens				s			
E. spinulosum				s		s	
Eurhynchium	x	x	x		x	x	
E. pulchellum	s				s	s	
E. hians		s	s		s		
Fissidens	x	x	x	x	x	x	
F. cristatus	s				s		
F. bushii		s					
F. taxifolius		s	s	s			
F. obtusifolius				s	s		
F. dubius				s			
F. kansanus					s		
F. bryoides						s	
Fontinalis			x	x			
F. novae-angliae			s				
F. duriaei				s			
Funaria			x	x	x	x	x
F. flavicans			s	s		s	
F. hygrometrica				s	s		s
Grimmia pulvinata				xs			
Haplocladium microphyllum					xs		
Homomallium					x		
H. adnatum					s		
H. mexicanum					s		
Hygroamblystegium tenax tenax			xs		xs		
Leptodictyum			x		x	x	x
L. riparium			s		s	s	s
L. laxirete						s	
L. trichopodium						s	s
Leptobryum pyriforme						xs	xs
Phascum cuspidatum					xs	xs	
Physcomitrium			x	x	x	x	x
P. pyriforme			s		s	s	s
P. hookeri				s		s	
Plagiomnium cuspidatum		xs	xs	xs	xs		xs
Platygyrium repens				xs	xs		
Pleuridium			x		x		
P. sullivantii			s				
P. subulatum					s		
Pogonatum pensilvanicum			xs				
Pohlia					x		x
P. wahlenbergii					s		
P. nutans							s
Polytrichum commune							xs
Pottia davilliana						xs	
Ptychomitrium incurvum				xs			

Appendix H (Continued)

Taxa	1	2	3	4	5	6	7
Sphagnum			x	x			x
S. contortum			s				
S. cupidatum			s				
S. fallax			s	s			
S. trinitense				s			
S. compactum							s
Steercleus		x	x		x		x
S. delicatulum		s					
S. serrulatus			s		s		s
Taxiphyllum taxirameum					xs		
Thuidium delicatulum		xs					
Weissia controversa	xs		xs	xs	xs	xs	xs
LIVERWORTS							
Asterella tenella			xs				
Cephalozia				x			x
C. connivens							s
C. lunulifolia				s			
Cephaloziella hampeana							xs
Chiloscyphus profundus			xs	xs			
Fossombronia			x	x			x
F. brasiliensis				s			
F. foveolata			s	s			s
Jamesoniella autumnalis				xs			
Lophocolea heterophylla							xs
Mannia fragrans						xs	
Oxymitra paleacea				xs			
Riccardia pinguis					xs		
Riccia			x	x	x	x	x
R. austinii					s		
R. beyrichiana						s	s
R. campbelliana				s			
R. dictyospora				s	s		
R. fluitans				s			
R. frostii					s		
R. hirta			s	s			
R. lamellosa				s			
R. sorocarpa				s			
Ricciocarpus nutans						xs	xs
Solenostoma gracillimum				xs			
Sphaerocarpus				x			
S. michelii				s			
S. texanus				s			

VERNALIZATION OF SHOOTING STAR ROOT-CROWNS AND ROOT–CROWN PARTS

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Abstract: The perennating root-crowns of shooting star (*Dodecatheon meadia*) consist of a large central bud on the summit of the crown proper surrounded by several to many radiating fleshy lateral roots of which some possess a small bud at their proximal end where they emerge from the crown. Following vernalization and subsequent development of the large central bud, the smaller (or barely visible) lateral buds (those associated with the fleshy lateral roots) degenerate and are thus squandered, having remained inactive owing to apical dominance. Consequently, the lateral buds represent an unexploited source of material for vegetative propagation. Surgical removal of a lateral bud and its associated fleshy lateral root and subjecting the unit to a minimum 75-day vernalization at 4°C followed by a 80-90-day growth period (GP) results in a plant substantially advanced in its development toward flowering. Plants given a repeat of the vernalization and GP can reach flowering in their second cycle. A certain amount of *in situ* increase in population density may be attributed to injury of the terminal bud that brings about activation of the several to many lateral buds. Greenhouse experiments involving mature root-crowns from which the central bud has been surgically removed demonstrate this phenomenon.

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Key words: *Dodecatheon meadia*, flowering, perennating root-crowns.

It has been proposed that shooting star (*Dodecatheon meadia*) has an extended maturation period lasting perhaps as long as 5 or 6 years from the seedling stage to flowering (see Sørensen 1992, Fig 1, p. 22). Subsequent anecdotal information suggests the development time can last far longer and may even span a period of 9 years or more. Thus, reliance on the establishment of shooting star from spreading seeds can be a discouraging endeavor. For these reasons it seems worthwhile to develop methods of propagating the species by vegetative means that circumvent the seedling stage especially for small-scale restorations where results within a short period of time yield a measure of satisfaction warranted from a modest amount of labor-intensive effort. The following narrative reports:

1. The fundamental means of vegetative propagation employing artificial vernalization.
2. A preliminary test of a way to greatly increase the number of progeny from vegetative propagation.
3. The minimum number of growth periods (GP's) necessary to bring individuals derived from specialized divisions into the flowering stage.

The simplest form of vegetative propagation of perennial plants requires merely that the crown be divided from time to time and the parts replanted. This was described for shooting star (Sørensen 1984, 1992) which, after a few years of growth in a particular location, develops a root-crown system consisting of a mass of intertwined fleshy roots attached to one of several crowns (Fig. 1) on which there is a bud (the "central bud") that will produce the next season's aerial parts. This method of propagation routinely yields a successful increase in the number of plants.

However, it has limitations for several reasons:

1. The replanted root-crowns require 3 or more years of development to produce a system capable of being divided again
2. The procedure usually requires working in a garden location in order to provide regular watering, owing to the fact that the divisions and replanting must take place during the dry period of the growing season (Sørensen 1984)
3. Mulching in the later part of the season is necessary to prevent winter frost-heave of the replanted root-crowns
4. Finding and replanting plants in a natural grassland setting at a time when the plants are dormant and hence not readily located adds another measure of difficulty to the effort.

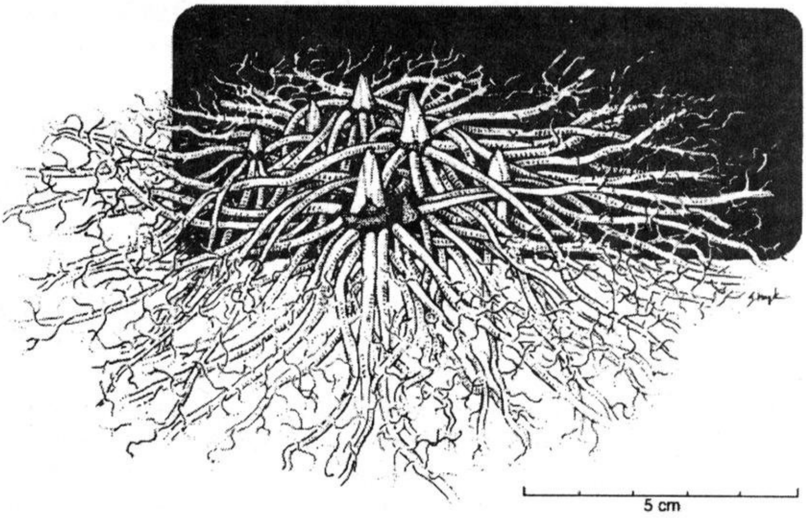

Fig. 1. Drawing of an intact root-crown system of shooting star lifted from an outdoor garden location in late July. This complex mass is the result of several years' development. Separating each of the buds with the associated fleshy lateral roots permits vegetative propagation resulting in 6 new individuals.

5. In a natural setting, it is seldom possible to provide water in sufficient amounts to reestablish the soil capillarity after the soil has been disturbed by the replanting.

Vegetative propagation by division of a well-developed root-crown system (Fig. 1) can, at best, produce only 7 individual plants, and a root-crown this size would only be produced after several years of growth. More commonly, a root-crown contains even less divisible material (Fig. 2) from which only 2 individual plants might be gained by cutting the crown in half. However, a close examination of an individual root-crown will reveal that surrounding the large central bud, one can often discern a ring of small **lateral buds** averaging 1.0-2.0 mm in length. They are located at the point where the fleshy lateral roots are attached to the crown proper. Such a configuration of crown parts is shown in Fig. 2 and Fig. 3. Under normal circumstances, these numerous lateral buds do not develop. Instead, they degenerate and are lost owing to apical dominance.

In spring, at the start of the growing season, the large central bud sprouts to produce a rosette of leaves followed by the lengthening flower stalk. During this period of growth and elongation, the central bud exerts an apical dominance over all other meristematic tissues that are otherwise capable of developing aerial parts. This prevents the lateral buds from further development. In an attempt to demonstrate that apical dominance is at work here, a root-crown (corresponding to the one shown in Fig. 2) was subjected to a vernalization of 75 days at 4°C. After that, the central bud was removed and its base excavated with a sharp spoon-like instrument to a point at which only the tissues of the crown perimeter still held the mass together. The root-crown with all the fleshy roots still attached was then planted in a soil-free growing medium (Pro-mix B) in a 6-inch clay pot and placed in the greenhouse. After a few days, a ring of 6 small leafy rosettes appeared at the soil surface. The rosettes continued to increase in size, and after about 90 days began to yellow and wither indicating the onset of dormancy. When the growing medium was washed from the root mass, 6 small individual root-crowns had developed with no organic connection between any of them. **Thus, all the connecting tissues present at the start of the GP had senesced or rotted away**.

This trial demonstrated that the lateral buds can develop independently, and that they possess the potential for greatly increasing the number of vegetatively-propagated individuals. The observations from this trial may also explain why in some instances highly disturbed sites (e.g. along an equestrian trail) seem to have very dense stands of shooting star. Persons or hooved animals can injure the central/terminal bud, bringing about an activation of the lateral buds. But more importantly (from the point of view of propagation of shooting star), the long maturation period starting from seed is

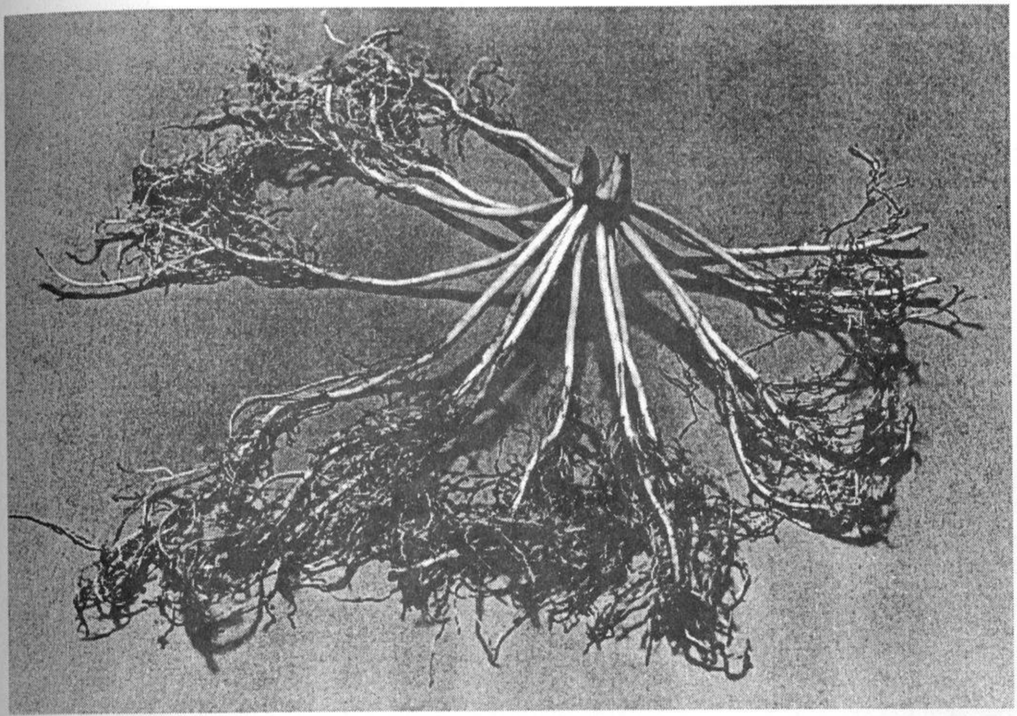

Fig. 2. A small root-crown with two large central buds. Cutting through the crown proper such that a bud remains on each of the 2 halves can yield 2 new individuals.

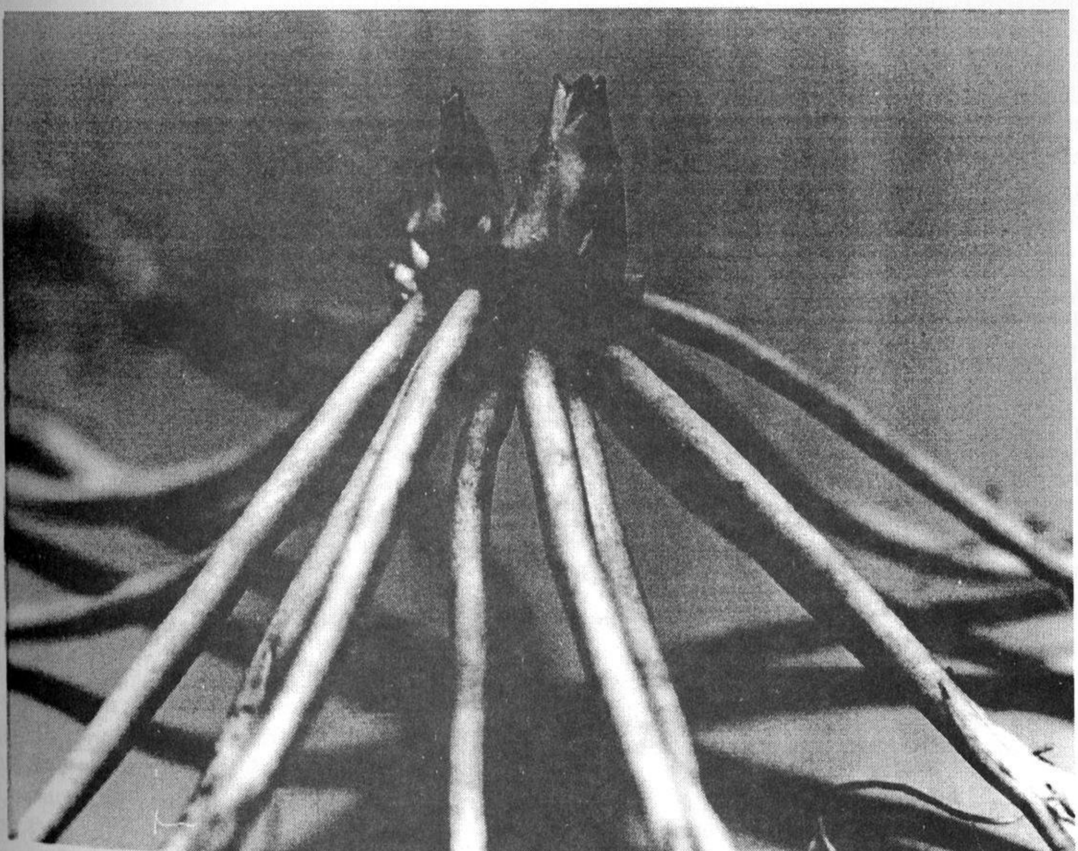

Fig. 3. Detail of the root-crown shown in Fig. 2. Note the several lateral buds at the base of the crown, each one associated with a fleshy lateral root.

circumvented because the propagation is initiated with an already enlarged organ. Knowledge of this has prompted us to ask the following question: What is the minimum length of time needed for a plant to reach flowering if one starts with a lateral bud that has been completely severed from the root-crown?

MATERIAL AND METHODS

To answer the question posed above, material was selected from a shooting star genotype that had earlier been extensively cloned by division and subsequent regrowth, such that we had available 7 large root-crowns, all genetically identical. These had been subjected to a minimum 75 days of vernalization at 4°C and were thus ready to begin their next GP. Using a narrow scalpel, 40 or more fleshy lateral roots with buds attached (Fig. 4) were removed. The fleshy laterals were chosen so as to leave behind some storage roots attached to the crown for nourishment of the large central bud. The height of the attached lateral buds was measured using a dial caliper (Table 1). Each root was then trimmed to 6.5 cm and weighed (Table 2). The laterals were planted in a soil-free medium (pro-mix B) in 4-inch square-form plastic pots with the bud end near the center and just beneath the surface. The medium was then moistened to saturation with water to which had been added a commercial root-promoting growth hormone (Hormex) at the rate of 12 drops/gallon. The severance, measurement, and planting took place on 22 April 1997. The 80-day GP concluded on 10 July, at which time each plant had developed a small root-crown with a **central bud** (an immature version of the apparatus shown in Fig. 2). These newly-developed root-crowns were washed, trimmed, measured, weighed, and laid out in layers between moist paper-toweling in a plastic storage container with a sealable lid and given a vernalization of 75 days at 4°C. These procedures were carried out through 3 GP's (GP):

1st GP	22 Apr to 10 Jul 1997
Vernalization	10 Jul to 24 Sep 1997
2nd GP	24 Sep to 15 Dec 1997
Vernalization	15 Dec 1997 to 2 Mar 1998
3rd GP	2 Mar to 20 May 1998

RESULTS AND DISCUSSION

The goal of the manipulation of shooting star root-crowns was to derive vigorous flowering plants in as brief a period as possible. Tables 1 and 2 show that for the duration of the experiment the below-ground biomass increased substantially through the GP's; however, the length of the central bud declined slightly (average 1.73 mm decrease) from the 2nd through the 3rd GP. The latter decline might be due to the fact that during the 3rd GP each of the maturing root-crowns added a large number of lateral buds (Table 3). They more than doubled from an average of 3.4 lateral buds per root-crown to an average of 11.4, an increase of 335%!

Meanwhile, already during the 2nd GP, 3 plants produced small inflorescences. During the 3rd GP, 7 of 36 plants did not produce flowers (Table 4). Interestingly, the root-crown (C1) that produced the largest increase in lateral buds (from 0 to 15) was 1 of those that failed to flower. Similarly, plant A3, 1 of the 3 that flowered in the 2nd GP (Table 4), declined in the number of flowers produced in the 3rd GP while the number of lateral buds produced increased from 5 to 19. Thus there appears to be a kind of resource partitioning that the present experiment cannot explain. It follows this pattern: through successive GP's the overall biomass of the root-crowns increases while the height/length of the **central** bud does not, and the latter may even decrease while the number of **lateral** buds increases remarkably. There may be a decline in the number of flowers produced in an inflorescence if lateral buds are produced instead.

Presently, the root crowns that finished their 3rd GP on 20 May 1998 have been placed in cold for yet another vernalization. When they are removed from cold and repotted, it is expected that all 36 of them will produce flowering plants and that a significant number will have reached the size where several or many fleshy lateral roots with an associated bud (Fig. 4) can be removed to begin the process of multiplication over again.

The lapsed time from the start of this experiment to the derivation of mature, flowering plants totaled 393 days. A trial in an outdoor garden yielding similar results but not involving artificial vernalization would require a full 3 years.

CONCLUSION

Normal growth of shooting star results in the loss of large amounts of useful parts of the complex root-crown system due to the phenomenon of apical dominance of the terminal/central bud that suppresses the development of the lateral buds. After a vernalization of the root-crown (minimum of 75 days at 4°C), the severance of the lateral buds from the influence of the terminal bud permits the lateral bud to develop as a separate plant, producing a small root-

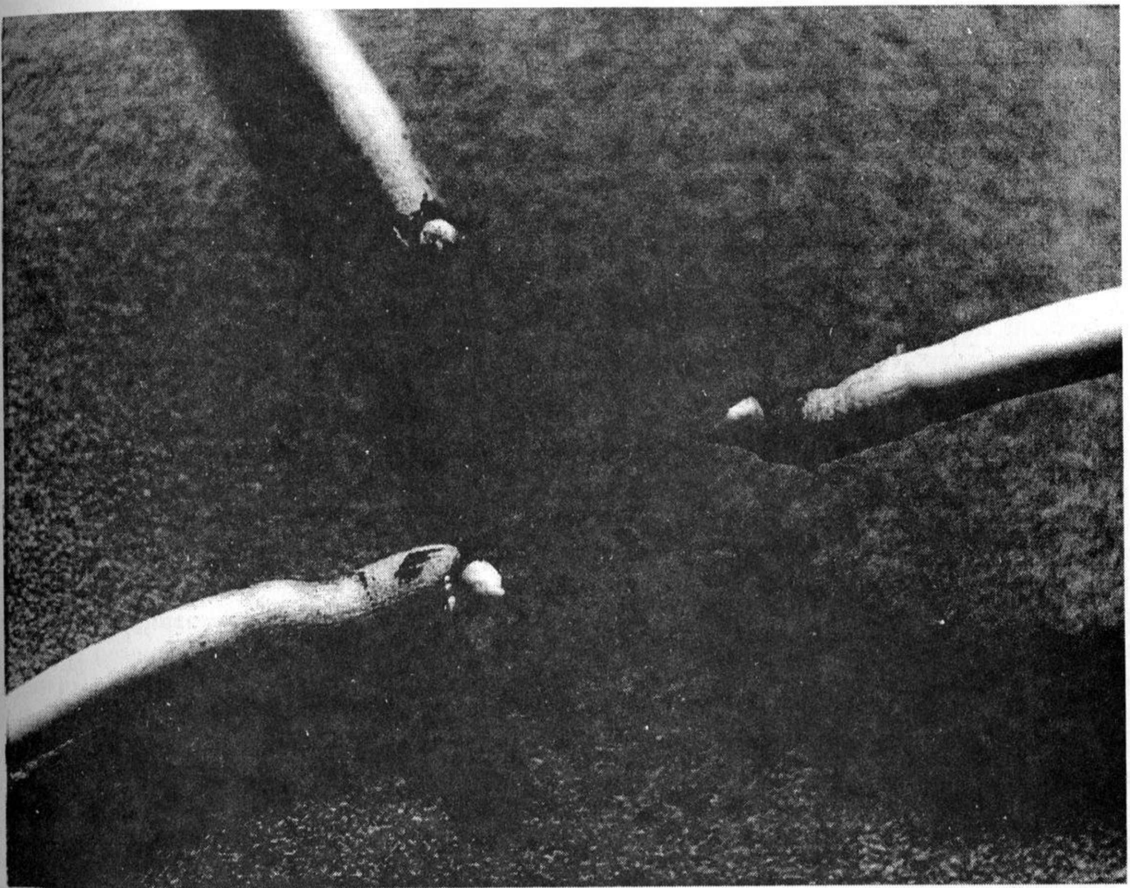

Fig. 4. Fleshy lateral roots severed from the root-crown with the lateral buds attached. Each of these can be planted separately and will produce individual plants much advanced in development over a seedling.

crown that is considerably advanced toward flowering maturity, thus bypassing the long maturation period (5 - 9 years) associated with development from seed. Subsequent cycles of vernalization followed by a minimum 80-day GP can bring about flowering maturity in a substantial number of the new individuals—in about one-third or less the time required for plants left outdoors in a garden setting. This procedure salvages large amounts of valuable plant material that would otherwise be lost. Although labor-intensive, the prospect of establishing shooting star in early stages of a prairie restoration project make the effort well worthwhile.

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MANIPULATION OF SOIL RESOURCE HETEROGENEITY IN A TALLGRASS PRAIRIE RESTORATION

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Abstract: Plant species diversity in native prairie ecosystems is influenced by heterogeneity of soil resources, which results from interactions among plant communities, soil properties, topography, and disturbance. Key factors which promote plant diversity in native prairie include soil moisture, rooting depth, and nutrient availability. Most prairie restorations in the Great Plains occur on former agricultural land and the soil template for these restorations has been physically homogenized through tillage practices. The reduction in soil resource heterogeneity in restored prairies may be causally related to low plant species diversity commonly encountered in these sites. To examine the role of soil heterogeneity in restoring prairie ecosystems, replicated blocks (n=4) of 4 plots consisting of different levels of soil heterogeneity were established in an agricultural field. The 4 plot types included: control (least heterogeneous with respect to soil resources), altered plant rooting depth, altered nutrient availability, and combined variation in plant rooting depth and nutrient availability (maximum heterogeneity). Plant rooting depth was varied by burying limestone barriers at 25 cm to create alternating strips of deep and shallow soil. Variation in soil nutrient (inorganic N) availability was established via increased N (+fertilizer), decreased N (+ recalcitrant C), and no change in N. All plots were seeded with the dominant native grasses and >30 forb species. Incorporation of recalcitrant C reduced total inorganic N availability 90% as a result of 98% reduction in available nitrate. Plots containing strips of low N availability exhibited significantly ($p < 0.05$) greater spatial variability than plots without this manipulation. Thus, the experimental design and methods implemented have increased heterogeneity of soil nutrients, and this will enable us to address the role of variation in soil resources on restoring tallgrass prairie.

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Key words: altered soil nutrient availability, altered plant rooting depth, Great Plains, limestone barriers, recalcitrant C, soil template, species diversity.

Tallgrass prairie historically occupied approximately 60 million ha in the eastern third of the Great Plains region, and today only 4% of this ecosystem remains unplowed from agriculture (Samson and Knopf 1994). The majority of tallgrass prairie was lost to row crop systems because the most ideal conditions for soil aggregate formation, hence productive capability of soils, occur in grasslands (Allison 1968). Recently, increased interest in prairie restoration and incentives to reduce erosion have led to many grassland restorations on former cropland (Gebhart et al. 1994). The most commonly employed restoration approach is sowing the dominant, native, perennial grasses (Dunn et al. 1993), and establishment of these grasses is often successful (Sperry 1994, Wilson and Gerry 1995). However, less common grass and forb species, responsible for the high diversity of undisturbed tallgrass prairie, are inadequately repre-sented in many prairie restorations.

Diversity in tallgrass prairie ecosystems is maintained in part through plant-induced mechanisms, soil nutrient availability, topographic variation, and disturbance. For example, presence or absence of plants (Vinton and Burke 1995) and association of particular plant species (Wedin and Tilman 1990, Robles and Burke 1997) strongly influences variability in soil carbon (C) and nitrogen (N) pools. Lower species diversity observed in experimental grassland plots receiving long-term fertilizer additions (e.g. Collins and Steinauer 1998) provide indirect evidence that N-limitation and heterogeneity of soil N-pools promote diversity in prairie ecosystems (Inouye and Tilman 1995, Milchunas and Laurenroth 1995). Furthermore, topographic gradients include shallow upland soils with greater plant diversity than lowland sites, presumably due to reduced soil depth and water availability to plants (Gibson and Hulbert 1987, Schimel et al. 1991).

Our working hypothesis was that lower diversity in restored prairie on former cropland compared to native prairie likely results from differences in soil resource heterogeneity. Practices such as long-term conventional tillage, uniform application of fertilizer, monospecific crop production, and annual harvest of aboveground biomass impart greater homogeneity on soil resources in agroecosystems compared to native systems. Effects of long-term cultivation on soil properties and processes in former grassland soils are well documented. Conventionally tilled soils exhibit altered soil aggregate structure, higher decomposition rates, and lower soil organic matter as compared to grassland soils (Anderson and Coleman 1985, Elliot 1986, Burke et al. 1995). Thus, the soil template at the onset of restoration in former agricultural soil may differ greatly from unbroken prairie.

The role of soil heterogeneity in prairie restoration has never been addressed experimentally, despite the recognition that variation in soil nutrient pools, plant rooting depth, and soil-water availability may promote floral diversity in native tallgrass ecosystems (Collins et al. 1998). Here we present a detailed description of the experimental design and methodology being used in a new tallgrass prairie restoration experiment to address the role of soil resource heterogeneity in restoring species diversity. Additionally, the effectiveness of manipulations on spatial heterogeneity of inorganic N and establishment of native grasses are evaluated.

METHODS

Study Site

Sixteen experimental plots were established in an 3.2 ha agricultural field at Konza Prairie Research Natural Area (KPRNA) located 9 km south of Manhattan, Kansas (Riley County). Soils in this field were mapped as a Reading silt loam with 0-1% slope (mesic Typic Arguidoll), and has been cropped continuously for about 50 years (Dodds et al. 1996). Unplowed deep lowland soils at KPRNA similar to this site are formed by colluvial and alluvial deposits and are typically dominated by warm-season (C_4) grasses such as big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and little bluestem (*Andropogon scoparius*), interspersed with a variety of other plant species. Floristic diversity at KPRNA is relatively high, with over 250 species occuring in native prairie habitats (Freeman 1998). Elevation is about 340 m above sea level, and average precipitation is 853 mm/yr (30-year average). Following harvest of the field in June 1997, residual crop litter and stubble were burned. Corners of all 16 plots and 3 random points within each plot were delineated and relative change in elevation measured with a level transit station.

Experimental Design

Replicated blocks (n = 4) consisting of 4 6–m x 8–m plots with different levels of soil resource heterogeneity were established (Fig. 1). Treatments were randomly assigned to plots within each block with a 6-m buffer strip between plots. The 4 treatments within each block included control, manipulation of available soil N, manipulation of plant rooting depth, and combined manipulation of both plant rooting depth and soil nutrient availability. Each plot was subdivided into 12 2-m x 2-m subplots for sampling (n = 192).

Manipulation of Soil Resources

Variation in plant rooting depth (and soil-water availability) was accomplished by burying native limestone slabs. Four 6-m x 62-m strips containing all experimental plots were excavated to a depth of 25 cm with a road grader and track loader. In plots designated for variation in plant rooting depth, rough cut limestone slabs 3-6 cm thick, ranging from 0.4 m to 0.7 m in width and length, were pieced together in 2 alternating 2-m x 6-m strips (Fig. 1). Crevices between limestone slabs were filled with limestone gravel. Following placement of limestone strips, soil was replaced in all plots with the same equipment used in excavation. Once the excavated soil settled, the area was leveled with a dual blade attachment towed from a tractor (commonly used to redistribute gravel roads). In Fall 1997, the soil was lightly cultivated (2-3 cm deep) to reduce establishment of weedy species.

Soil N heterogeneity was manipulated by altering N availability in 3 randomized 2-m x 8-m strips within experimental plots. Strips with reduced nitrogen availability were established in February 1998 by adding a recalcitrant form of C (sawdust) to immobilize nitrogen. Using a total soil C content (0-15 cm) and bulk density of 1.5% and 1.2 g/cm^3, respectively, estimated total soil C of the field site was 2.7 kg/m^2. Sawdust was added to increase the C content to a level representative of prairie soils (≈ 3% C or 2 times existing C content). Carpentry sawdust (49% C) was tilled into the top 15 cm of soil at a rate of 2.7 kg of C/m^2. All plots were tilled at this time to maintain similar conditions among plots for planting. Strips with increased nitrogen availability were fertilized by applying ammonium-nitrate (35%

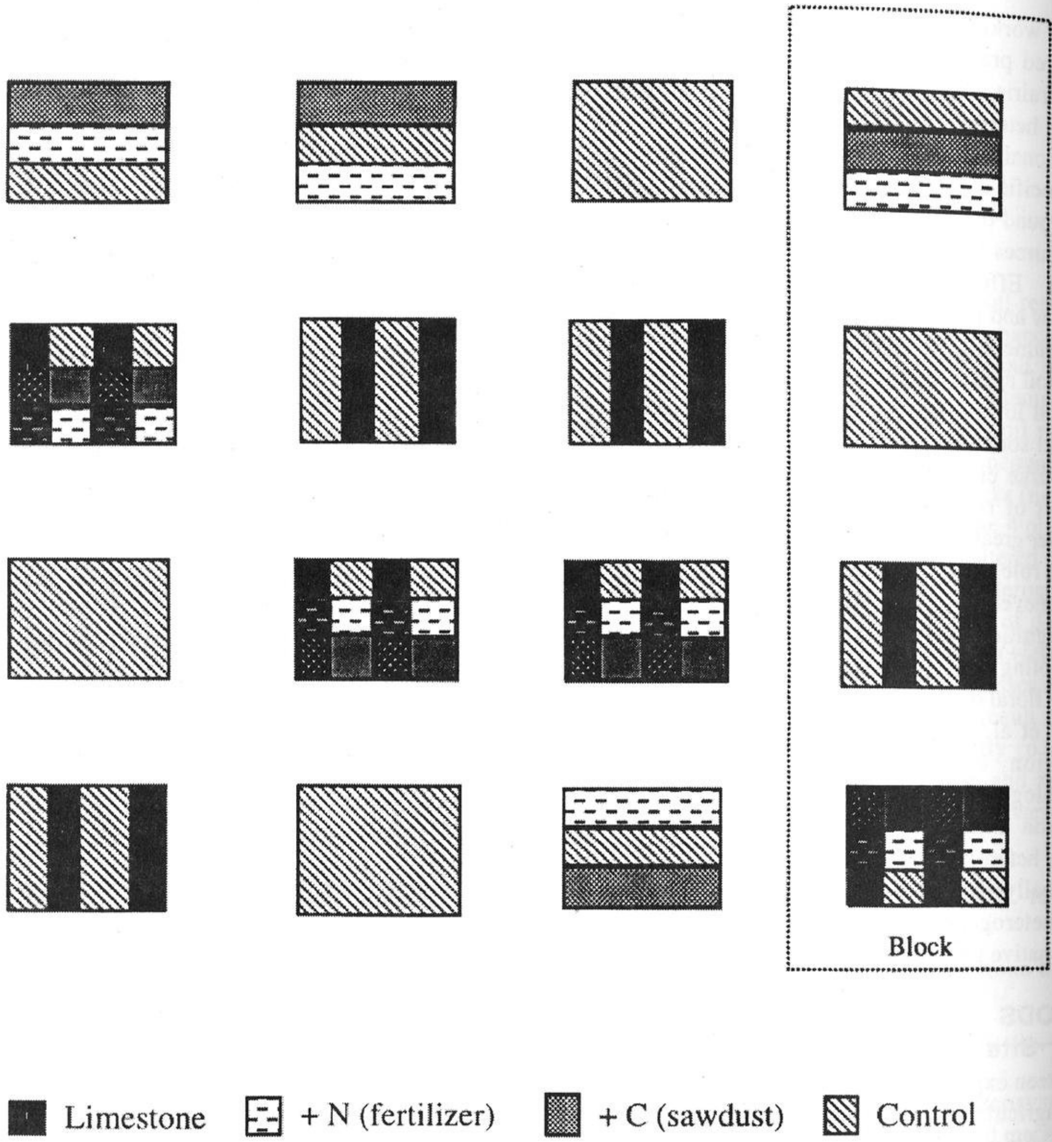

Fig. 1. Tallgrass prairie restoration experimental design. Four replicated blocks containing 4 6-m x 8-m treatment plots represented different levels of soil heterogeneity. Control plots received no manipulations and were least heterogeneous with respect to soil resources. Greater soil resource heterogeneity was achieved in plots receiving either alternating buried 2-m x 6-m strips of limestone or 3 randomized 2-m x 8-m strips of N availability. Maximum soil resource heterogeneity was represented in plots containing both limestone and N treatments.

N) at a rate of 5 g of N/m^2 (14.3 g of fertilizer/m^2) in July 1998. Fertilizer application was delayed until July, since initial N levels were relatively high at the onset of the experiment.

Maximum soil resource heterogeneity plots contained both the manipulations of plant rooting depth (alternating 2-m x 6-m strips of buried limestone) and altered nutrient availability (randomized 2-m x 8-m strips of variation in N). All plots (including controls) were initially excavated to a depth of 25 cm and were tilled or cultivated simultaneously to control for variation that may result from this disturbance.

Restoration Methods

All plots were sown to native prairie species in April 1998. The dominant grasses (big bluestem, Indiangrass, switchgrass and little bluestem) were obtained from a local distributor in Kansas (Star Seed Inc., Beloit, KS) and less common grass and forb seed was either hand-collected locally or purchased from commercial sources (Appendix). All seeds were kept in cold dry storage until planting. Species and seeding rates selected were chosen to achieve a log-normal distribution of species representative of prairie habitats on Konza Prairie. Forty-two prairie species were assigned to 1 of 4 frequency categories and seeded at the following rates: dominant grasses (160 seeds/m^2), common (16 seeds/m^2), frequent (10 seeds/m^2), or uncommon species (5 seeds/m^2). With the exception of legumes, seeds were not treated to promote germination. Legume seeds were inoculated with species specific *Rhizobia* mixtures obtained from Prairie Moon Nursery (Winona, MN) just prior to planting. Average weight of 3 replicates of 100 seeds of each species was used to determine total weight of each species required per plot based on the frequency category assigned to each species.

Prior to planting, all plots were lightly raked. Less common grass and forb seeds were mixed with damp builders sand and hand broadcast evenly over plots. The dominant grass species were seeded with a grass drill (Truax Co., MN) designed to deliver fluffy grass seed at a uniform rate to a depth of 1.2-2.5 cm. Dominant grasses were seeded at the same rate (approximately 17 lbs/acre) within and between all plots to reduce potential edge effects. Following planting, prairie hay harvested the previous summer from KPRNA was spread on all plots to retain soil moisture, promote soil seed contact, and minimize loss of seeds by wind. Prairie hay was harvested before dominant grasses set seed, so the contribution of seeds to study plots from this source was considered minimal, and any seed within the prairie hay should further promote a log-normal distribution of species.

Plant Rooting Depth

In January 1998, plant rooting depth in limestone strips was assessed by measuring depth of soil to buried limestone with a graduated metal probe. Soil depth to limestone readings were taken in each subplot (3/strip or 6/plot) representing this treatment (n = 48).

Establishment of Native Grasses

In July 1998, establishment of native grasses planted was examined from 1-m transects delineated by a pin frame through the center of each subplot (n = 192). At 20-cm intervals, the dominant native grass closest to that pin was identified and measured to assess the relative contribution of each species to dominant grasses established and examine effects of the different treatments on plant growth (height).

Inorganic N Availability

In June 1998, 2 soil samples (0-10 cm depth) were taken from each subplot with a 2-cm diameter core and composited. Sampling occured prior to N addition and approximately 4 months following incorporation of sawdust. Samples were passed through a 4-mm sieve to homogenize the soil and remove large pieces of plant debris. Inorganic nitrogen (NH_4-N and NO_3-N) content was determined by extracting 10-12 g of field moist soil with 50 mL of 2 M KCl on an orbital shaker for one hour, then filtering the suspension through a 0.4–mm polycarbonate membrane. Inorganic N concentrations were analyzed colorimetrically with an Alpkem Flow Solution autoanalyzer using the phenol blue method for NH_4-N and nitrate reduction to nitrite followed by diazotization for NO_3-N determinations. A subsample of approximately 50 g field moist soil was weighed, dried for 2 d at 60°C, and reweighed to determine gravimetric soil-water content.

Analyses

Means and standard errors were calculated for height of dominant grass species and inorganic N concentrations (NO_3-N, NH_4-N, and total inorganic N) from subplots representing each treatment: control (n = 120); addition of recalcitrant C only, +C (n = 24); reduced rooting depth, + Limestone (n = 40); and combined treatments, Limestone + C (n = 8). Spatial variability of inorganic N availability following incorporation of recalcitrant C (prior to fertilization) was analyzed using a random-ized complete block design. Differences in variab-ility among treatments were examined with a one-way analysis of variance (ANOVA, $\alpha = 0.05$) on coefficients of variation (CV) for each of the 4 treatments determined from the 12 subplots within each treatment plot (SAS Institute 1989).

RESULTS AND DISCUSSION

Emergence of grass seedlings occurred approximately 6 weeks following planting and the height of dominant grasses by mid-summer ranged from 8 to 106 cm. Percent contribution of big bluestem, Indiangrass, switchgrass and little bluestem to the total grasses examined (n = 960) were 34%, 28%, 21%, and 15%, respectively. Big bluestem and Indiangrass were the most frequently encountered native grass species in most treatments. All domin-

Table 1. Mid-summer (July 1998) average height (standard error) of dominant native grass species seeded in April 1998. Averages for each treatment combination were determined from 5 grasses in each of 192 subplots (number of grasses examined, n = 960). Treatments included: control (n = 600, 120 subplots); Limestone (n = 200, 40 subplots), +C (n = 120, 24 subplots), and Limestone + C (n = 40, 8 subplots).

		Control	Limestone	+C	Limestone + C
Andropogon gerardii	avg	41.2 (1.1)	38.1 (1.6)	26.1 (1.9)	22.9 (2.7)
	n	190	78	50	15
Andropogon scoparius	avg	26.1 (1.1)	27.0 (1.5)	18.1 (2.6)	15.3 (4.8)
	n	94	33	18	7
Panicum virgatum	avg	47.6 (1.2)	48.5 (2.2)	33.3 (4.1)	23.3 (3.2)
	n	136	45	17	7
Sorghastrum nutans	avg	36.2 (1.0)	37.3 (1.8)	27.5 (1.7)	20.2 (2.9)
	n	180	44	35	11

ant grass species we planted responded similarly to the treatments in place at the time of this investigation (Table 1). Average plant height was 23-37% lower in the sawdust treatment as compared to control subplots. Growth of the dominant grasses was further inhibited in combined sawdust and limestone treatments (e.g., average height was 44-51% lower than unmanipulated subplots). Responses of dominant native grasses to the treatments were likely related to differences in soil resources, particularly inorganic N availability.

The treatments appear to have promoted the desired heterogeneity in soil resources. In plots containing buried strips of limestone, plant rooting depth has been reduced to an average 24.7 ± 3.1 cm, ranging from 9 to 30 cm. Incorporation of recalcitrant C (sawdust) was effective in reducing inorganic N availability (Fig. 2). Average total inorganic N was > 90% lower in C addition and combined limestone and C treatments compared to control subplots. Substantial reductions in total inorganic N resulted primarily from reduced production or enhanced consumption of NO_3-N. The average NO_3-N concentrations in C addition subplots were only 2% of NO_3-N concentrations in control plots. Coefficients of variation of total inorganic N and NO_3-N from the treatment plots receiving additional C were significantly greater than plots which did not receive sawdust (Table 2). Thus, recalcitrant C addition in randomized strips successfully enhanced spatial heterogeneity of inorganic N, particularly NO_3-N, in plots receiving this treatment.

As expected, inorganic N concentrations at the onset of restoration were high relative to undisturbed prairie soils. Potential fates of NO_3-N in soil (whether derived from fertilizer or mineralized from soil organic matter) include plant uptake, leaching, or microbially-mediated transformations (Paul and Clark 1996). At the time of our initial sampling, plants in restoration plots were just beginning to establish, so plant uptake of NO_3-N was considered negligible. Thus, microbial processes were likely responsible for changes in inorganic N availability.

Several mechanisms are potentially responsible for the reduction in inorganic N in the C addition treatments. Cropland soils generally exhibit lower CO_2 evolution, lower N-immobilization, and greater net N-mineralization rates than grassland soils, suggesting that the microflora of tilled agricultural soils are C-limited whereas grassland soils are N-limited (Schimel 1986). Addition of recalcitrant C to cropland soil likely alleviated C limitation, stimulated microbial activity, and increased immobilization of inorganic N in the microbial biomass. Second, microbes generally prefer to assimilate NH_4-H (Jones and Richards 1977), but microbial assimilation of NO_3-N at soil microsites where NH_4-N is not available may partially account for immobilization of inorganic N through dissimilatory reduction of nitrate to ammonium (Davidson et al. 1990). Third, enhanced immobilization, or a reduction in net N mineralization may have resulted in lower rates of nitrification by reducing availability of ammonium. Finally, conversion of nitrate to dinitrogen gas (denitrification) demands high levels of

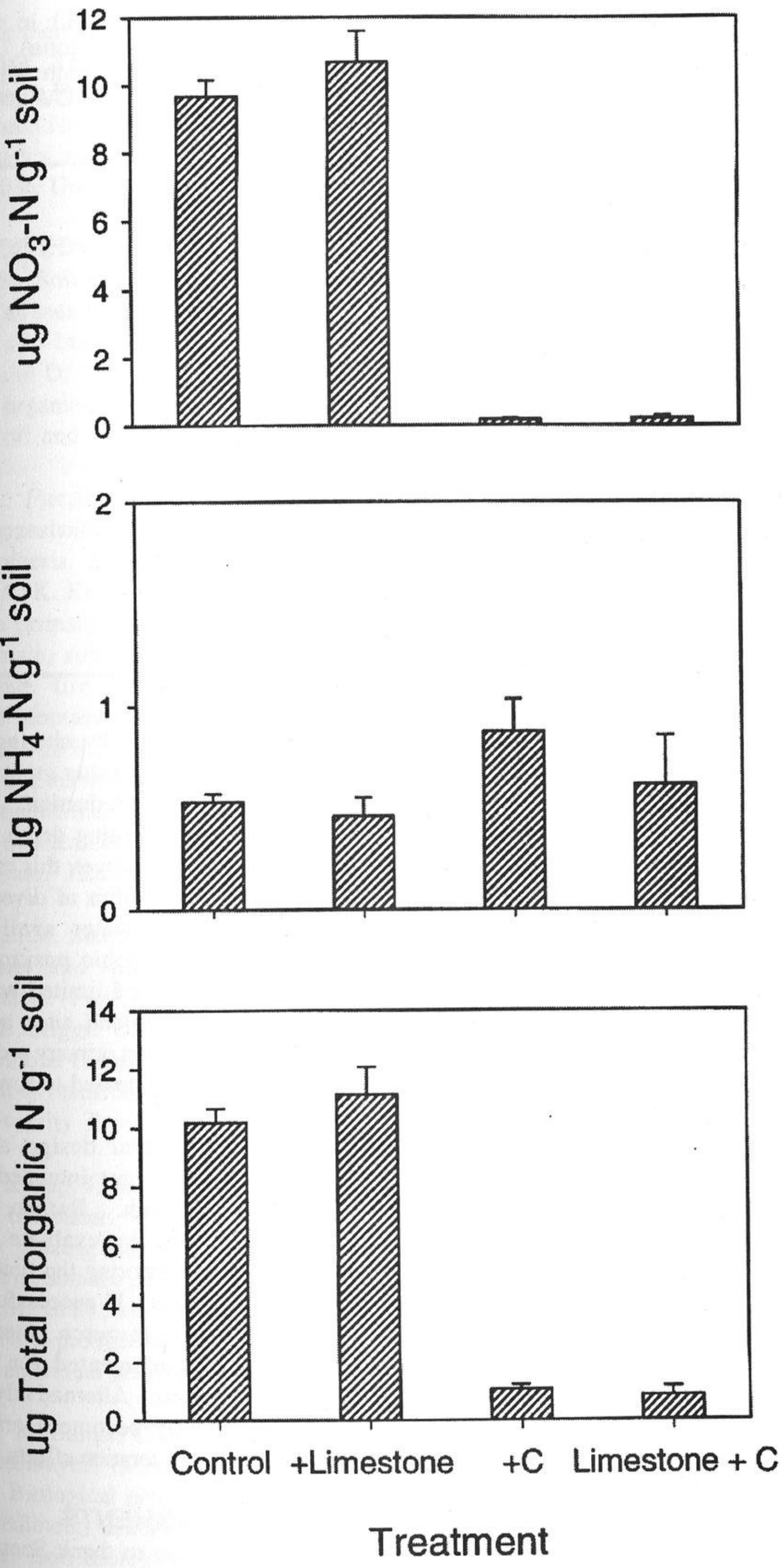

Fig. 2. Average (± standard error) NO_3-N, NH_4-N, and total inorganic N concentrations from subplots representing 4 treatments: control, carbon addition (+C), buried limestone (+Limestone), and combined carbon addition and buried limestone (Limestone + C).

Table 2. Mean and coefficients of variation (CV) for inorganic N (µg/g soil) in restoration plots representing 4 treatments: control, manipulation of rooting depth (+Limestone), manipulation of inorganic N availability (+Carbon), and combined manipulation of rooting depth and N (Limestone + Carbon = maximum heterogeneity). Significant differences in average CV (n = 4) between treatments indicated by different letter superscript ($p < 0.05$, 1-way ANOVA).

Treatment		NO_3-N	NH_4-N	Total Inorganic N
Control	Mean	6.98	0.45	7.43
	CV (%)	44.83[a]	52.42	39.73[a]
+ Limestone	Mean	12.32	0.47	12.79
	CV (%)	28.34[a]	105.47	27.85[a]
+ Carbon	Mean	6.09	0.68	6.76
	CV (%)	84.98[b]	66.14	75.28[b]
Limestone + Carbon	Mean	6.05	0.55	6.6
	CV (%)	101.62[b]	72.04	90.95[b]
	F	17.78	0.89	16.82
	Pr > F	0.0002	> 0.05	0.0002

nitrate, C, and anaerobic soil microsites (Tiedje 1988). Sawdust addition may have provided conditions for enhanced denitrification. However, this seems unlikely because a previous study of denitrification in this agricultural field revealed low denitrification potential (N + C ammended soil) in the surface interval of the soil profile (Sotomayer and Rice 1996).

Increased spatial heterogeneity of soil inorganic N as a result of C addition was evident, and we predict that variation in N resulting from this manipulation will influence restoration of species diversity. Nitrogen availability strongly influences diversity and productivity in tallgrass prairie ecosystems (Seastedt and Knapp 1993, Blair 1997). Experimental plots annually burned and fertilized (+ 10 g of N/m^2) from 1989 to 1994 at KPRNA exhibited a 10-fold increase in soil inorganic N, greater aboveground biomass, and lower species richness of C_3 grasses, forbs and woody plants compared to control plots (Collins et al. 1998). Lower diversity in these plots may be influenced by greater homogeneity in soil N availability and relief of N limitations characteristic of tallgrass prairie soils.

Thus far, the treatments imposed have successfully promoted heterogeneity in the soil environment with respect to N availability and plant rooting depth. Response of dominant native grasses to treatments, specifically reduced growth in plots receiving additional C, may further promote resource heterogeneity in plots by altering light availability, aboveground organic matter inputs, and belowground root distribution and production. Although effects of manipulated plant rooting depth (buried limestone) could not be evaluated yet, this manipulation should also promote restoration of diversity by providing variability in soil-water availability to plants. Variation in topographic position results in areas with shallow soils and limited water availability to plants. Shallow upland sites at KPRNA exhibit lower aboveground net primary production but greater species diversity compared to lowland areas (Briggs and Knapp 1995).

The experimental design and manipulations described here are not intended to be used as a restoration approach. Rather, the goal of this investigation was to evaluate the role of soil heterogeneity in restoring the function and diversity of tallgrass prairie. If successful, other means of manipulating soil resource heterogeneity may be designed and implemented for specific types of restoration projects. Alternatively, site-specific soil heterogeneity may become a criteria in choosing critical areas for restoration efforts.

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Appendix. Restoration species, planting rate (seeds/m²), and seed sources. Seed source abbreviations: a = Star Seed Inc., Beloit, KS; b = Ion Exchange, Harper's Ferry, IA; c = Iowa Prairie Seed Co., Sheffield, IA; d = Hamilton, Elk Creek, MO; e = Prairie Moon Nursery, Winona, MN; f = hand-collected from Flint Hills region, Riley Co., KS.

Common Name	Species	Seeding Rate	Seed Source
big bluestem	*Andropogon gerardii*	160	a
Indian grass	*Sorghastrum nutans*	160	a
little bluestem	*Andropogon scoparius*	160	a
switchgrass	*Panicum virgatum*	160	a
blue sage	*Salvia azurea*	16	d
Canada goldenrod	*Solidago canadensis*	16	b
heath aster	*Aster ericoides*	16	b
prairie sage	*Artemisia ludoviciana*	16	c
sideoats grama	*Bouteloua curtipendula*	16	b
aromatic aster	*Aster oblongifolius*	10	b
false boneset	*Kuhnia eupatorioides*	10	f
inronweed	*Vernonia fasciculata*	10	f
junegrass	*Koeleria pyramidata*	10	b
leadplant	*Amorpha canescens*	10	f
low goldenrod	*Solidago missouriensis*	10	f
New Jersey Tea	*Ceanothus herbaceous*	10	f
prairie dropseed	*Sporobolus heterolepis*	10	b
purple prairie clover	*Dalea purpurea*	10	b
roundhead lespedeza	*Lespedeza capitata*	10	b
sensitive briar	*Schrankia nuttallii*	10	d
tall dropseed	*Sporobolus asper*	10	b
whorled milkweed	*Asclepias verticillata*	10	b
blue-eyed grass	*Sisyrinchium campestre*	5	b
dotted blazing star	*Liatris punctata*	5	f
false blue indigo	*Baptisia australis*	5	f
fringed-leaf ruellia	*Ruellia humilis*	5	b
Illinois bundleflower	*Desmanthus illinoensis*	5	f
large flowered beard tongue	*Penstemon grandiflorus*	5	b
Missouri evening primrose	*Oenothera macrocarpa*	5	f
peppergrass	*Lepidium densiflorum*	5	f
prairie coneflower	*Ratibida columnifera*	5	b
prairie ragwort	*Senecio plattensis*	5	e
prairie rose	*Rosa arkansana*	5	b
purple beard tongue	*Penstemon cobaea*	5	f
purple cone flower	*Echinacea angustifolia*	5	b
purple poppy mallow	*Callirhoe involucrata*	5	d
silky aster	*Aster sericeus*	5	b
spider milkweed	*Asclepias viridis*	5	f
Venus looking glass	*Triodanis perfoliata*	5	e
white prairieclover	*Petalostemum candidum*	5	b
wild alfalfa	*Psoralea tenuiflora*	5	f
wild blue indigo	*Baptisia bracteata*	5	b

PROJECTED EASTERN REDCEDAR CANOPY EXPANSION ON A NEBRASKA LOESS HILLS SITE

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Abstract: Eastern redcedar *(Juniperus virginiana* L.) is increasing in area and numbers on Nebraska Loess Hills grasslands. This is having broad ecological and economic effects, and active management will be required to prevent a transition from grassland to woodland. We calculated the rate of eastern redcedar canopy expansion during 24 years on a Loess Hills site under 5 management options. We also conducted a net present value analysis of costs and returns from the 4 action options. The results showed that the canopy-expansion rate rapidly will increase without management action, permitting more than 85% canopy cover to develop in 24 years. The economic analysis indicated that prescribed fire applied every 8 years provides better net returns than no action, more frequent fire, or fire plus selective herbicide application.

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Key words: forest encroachment, *Juniperus virginiana* L., net-present-value analysis, prescribed fire, range improvement, tree-canopy expansion, woody-plant control.

Eastern redcedar (*Juniperus virginiana* L.) is native to the Nebraska Loess Hills (Kaul and Rolfsmeier 1993). In presettlement times the species primarily was restricted to mesic north aspects and canyons oriented so that trees were protected from fires driven by prevailing northwesterly winds (Webber 1889). Since about 1945, however, eastern redcedar has begun expanding onto other sites within the Loess Hills. Several factors, primarily relating to improved wildfire suppression, are cited as reasons (Schmidt 1991).

The expansion of eastern redcedar is having many profound effects, including those on ecosystem type, landscape appearance, wildlife distributions and numbers, native vegetation, watershed hydrology, and profitability of the local range cattle industry (Bragg and Hulbert 1976, Crathorne et al. 1982, Stritzke and Rollins 1984, Engle and Kulbeth 1992, Gehring and Bragg 1992, Rollins and Armstrong 1994, Thurow and Hester 1997). Cattle grazing is the leading private use of Loess Hills grasslands. Profits from that industry will be the primary source of any management inputs applied to counter eastern redcedar encroachment, and ranchers will be the decision makers. Although some observers have speculated about the development of a forest-products industry based on Nebraska eastern redcedar, this potential probably is overstated in that the growing supply appears to be outstripping any developing demand, and because eastern redcedar from the Nebraska Loess Hills is inferior to those from other in-state sources (Will 1998).

Most Loess Hills acreage still can be classified as grassland, rather than woodland or forest, despite varying degrees of eastern redcedar encroachment. However, because tree densities and areas occupied still are increasing, it appears inevitable that some sites will make state transitions from grassland to some woodland. According to the state-and-transition ecological model, once a system has transitioned into a different ecosystem type, reversing the trend is difficult and may require expensive and highly intensive management efforts (Friedel 1991). Conversely, maintaining a system in its present state is less expensive and mainly requires preserving the factors that shaped the original ecosystem type. Therefore, managers desiring to maintain property as predominately grassland would be prudent to act before the critical state transition point is passed.

The objectives of our study were to: 1) project the total eastern redcedar canopy expansion over 24 years on a Loess Hills site under 5 management options; and 2) compare the net present value of returns from the 4 action options with those from the no-action option at 3 interest rates.

STUDY AREA

We conducted our study on the Rowse Ranch on native rangeland in northeastern Custer County, Nebraska. The site was about 11 km (7 mi) west and 3 km (2 mi) south of Burwell, Nebraska. The legal description is Township 20N, Range 17W, Section 3, S 1/2 of SE 1/4. The Global Positioning System coordinates at the center of the study site are 41°43' 49.1" N, 99°15' 16.9" W. The area was typical of the Loess Hills eastern redcedar expansion area.

The predominate soil type was a Coly silt loam [fine-silty, mixed (calcareous), mesic Typic Ustorthent] formed in Peorian Loess (Soil Conservation Service 1982). Coly soils are somewhat excessively to excessively drained, occurring on canyon sides and narrow inter-canyon ridges. The canyon sides often have a succession of short vertical exposures called "catsteps" that expose the unaltered parent loess. The range site classification is Thin Loess.

The Custer County climate is continental, with cold winters and hot summers (Soil Conservation Service 1982). Mean annual precipitation is 572 mm (22.5 in), with about 80% of that usually falling from April through September. Winter snowfall is frequent, averaging 737 mm (30 in) per year. However, snow cover usually is not continuous; at least 25 mm (1 in) of snow is present an average of 18 days/yr. The average winter temperature is -3°C (27°F), and the average daily low is -11°C (12°F). The average summer temperature is 22°C (72°F) and the average daily high is 30°C (86°F). The average relative humidity mid-afternoon is 50%, but 80% at dawn. The prevailing winds are northwesterly. The average wind speed, 21 km/h (13 mi/h), is highest in April. Grazing on the site had traditionally been season-long continuous with cow-calf pairs. Range condition was estimated as about 75%. The vegetation was representative of the Loess Hills Mixed Prairie, as described by Weaver (1965). Dominate grasses were little bluestem [*Schizachyrium scoparium* (Michx.) Nash], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], blue grama [*B. gracilis* (H.B.K.) Lag. ex Steud.], and western wheatgrass [*Pascopyrum smithii* (Rydb.) A. Love]. Woody plants present included the shrubs leadplant [*Amorpha canescens* (Nutt.) Pursh], snowberry [*Symphoricarpos albus* (L.) Blake], common buffaloberry (*Shepherdia argentea* Pursh), chokecherry (*Prunus virginiana* L.), poison ivy [*Toxicodendron radicans* (L.) O. Ktze.], smooth sumac (*Rhus glabra* L.), currents (*Ribes* spp.), and blackberries (*Rubus* spp.). In addition to eastern redcedar, trees present included cottonwood (*Populus deltoides* Marsh.), hackberry (*Celtis occidentalis* L.), Siberian elm (*Ulmus pumila* L.), bur oak (*Quercus macrocarpa* Michx.), green ash [*Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl) Fern.], and Russian olive (*Elaeagnus augustifolia* L.). A variety of native forbs also occurred. The vegetational zonation described by Weaver (1965) was apparent, with taller species dominating near the canyon bottoms, grading to shorter species on the upper slopes. Deciduous trees were largely confined to north aspects, secondary draws, and footslopes.

Wildlife observed on the site included mule and white-tailed deer (*Odocoileus hemionus* and *O. virginianus*), turkey (*Meleagris gallopavo*), coyote (*Canis latrans*), porcupine (*Erethizon dorsatum*), and numerous species of raptors and smaller birds. The eastern redcedar population was of 2 distinct types; closed thickets of older, larger trees confined to primary and secondary north aspects, and younger stands of varying density on the other aspects. This research specifically dealt with the latter type, in that it was of more recent origin, in an early to mid-stage of expansion, and was more susceptible to control measures.

METHODS

Data Collection and Analysis

Data collected in 1993 and 1994 were used to calculate the eastern redcedar canopy-expansion projection. Trees were counted on 6.6 ha (16.3 ac) located on the east and west aspects of a steep, north-south oriented ridge. These trees also were measured and assigned to height classes, i.e., < 1 m, 1-2 m, 2-3 m, and > 3 m (< 3.3 ft, 3.3-6.6 ft, 6.6-9.8 ft, and > 9.8 ft). Total tree counts by height class used were, respectively 2,200, 800, 260, and 250 (Ortmann 1995).

About 60% of the 6.6-ha (16.3-ac) site were burned in a broadcast prescribed fire on 4 May, 1993. Fine-fuel loads averaged 2,670 kg/ha (2,490 lb/ac) on the site. Weather conditions during the burn were 24°C (75°F), 34% relative humidity, and 32 km/h (20 mi/h) winds from the SSE (Ortmann et al. 1998). Tree survival 1 year after fire was assessed and the probability of death to an individual tree of a given height was determined using logistic regression within the SAS Categorical Modeling Procedure (SAS Institute 1990). Logistic regression is designed to analyze non-normally distributed categorical data likely to have a sigmoidal response curve (Agresti 1990). This procedure yielded the function:

$$P = e^{3.15\ -\ 1.2(\text{height})}/1 + e^{3.15-1.2(\text{height})}$$

Next, the age-height relationship of the eastern redcedar population was determined. Approximately 25-mm thick (1-in) sections were cut from the bases of 125 randomly selected trees (Ortmann 1995). Heights were measured with a tape after the trees were felled. The cross sections were dried, sanded, and the annual growth rings counted to determine ages. The methods of Butler and Walsh (1988) were followed to avoid counting false rings. Annual growth rates were determined by dividing heights by ages. Because these results showed that it took about 8 yr for eastern redcedar to reach 1 m (3.3 ft) in height, an annual growth rate of 0.125 m (0.4 ft) was assumed for trees < 1 m (3.3 ft) tall. For trees > 1 m (3.3 ft) tall, the average annual growth rate was 0.19 m/y (0.6 ft/y). Thus as trees more than 1 m (3.3 ft) tall aged in the projection, 0.19 m (0.6 ft) was added per year.

Finally, the heights and basal canopy diameters of 50 standing eastern redcedar trees were measured (Ortmann 1995). The heights of 10 randomly selected trees were measured within each of 5 1-m (3.3 ft) height-increment classes, namely < 1 m, 1-2 m, 2-3 m, 3-4 m, and 4-5 m (< 3.3 ft, 3.3-6.6 ft, 6.6-9.8 ft, and 9.8-13.1 ft). The longest basal canopy diameter was measured, as was the diameter perpendicular to the first measurement. These were averaged and used to calculate the basal-canopy area for each tree (Engle and Kulbeth 1992). Area then was regressed on height, forcing the solution through the intercept on the assumption that a tree of 0 height would have a basal area of 0. This yielded the function:

$$\text{Area} = 0.04(\text{height}) + 0.36(\text{height})^2,\ r^2 = 0.89$$

Canopy-Expansion-Projection

The tree population on the study site was modeled under 5 management options. These were:

1 = no action.
2 = fire alone every 8 years.
3 = fire every 8 years plus supplemental herbicide control of all surviving trees < 3 m (9.8 ft) tall.
4 = fire alone every 4 years.
5 = fire every 4 years plus supplemental herbicide treatment of all surviving trees < 3 m (9.8 ft) tall.

The herbicide applied was Tordon 22K (4-amino-3,5,6-trichloropicolinic acid formulated as potassium salt) at a rate of 2 ml/m (2 ml/3.3 ft) of tree height, a reduced rate found to be effective on fire-damaged trees of this size (Ortmann 1995, Ortmann et al. 1996).

Using the functions and values described, the existing eastern redcedar population was aged for 24 years, and the height and basal area of trees increased accordingly. In addition, new trees were added to the population at the apparent recruitment rate at the time of data collection, i.e., 167/ha (67/ac) every 4 years. These new trees also were aged and grown as described. Then the total canopy coverage of the 6.6 ha (16.3 ac) could be calculated by multiplying numbers of trees of given ages by their appropriate basal-area values and summing the products. Finally, the complement of the probability of death due to fire was used as the probability of a tree surviving fire, e.g., 1.00 - 0.74 kill probability = 0.26 survival probability. Thus the tree population could be subjected to virtual fires and supplemental herbicide treatments at the specified time intervals and the surviving trees be retained in the population. These surviving trees then were used to calculate the new post-treatment canopy-cover percentages.

Economic Analysis

The costs and returns of the 4 action management options were compared to the no-action option and subjected to net present value (NPV) analysis at 3 annual interest rates. The NPV analysis was based on assumptions about the value of the grazing resource, and the costs of conducting prescribed fires and applying herbicides.

First, the value of grazing was based on a Thin Loess range site in Nebraska Vegetation Zone III (Waller et al. 1986) having an initial stocking rate of 1.48 AUM/ha/yr (0.6 AUM/ac/yr). An AUM (Animal Unit Month) is defined as the amount of forage necessary to support 1 animal unit for 1 month. In Nebraska, an animal unit is defined as a 1,000-pound lactating cow of above-average milk production with a calf less than 4 months old, or an equivalent nutritional demand made up of other sizes, classes, or species of livestock or wildlife. Under this convention, 1 AUM equals about 354 kg (780 lb) of air-dry forage (Waller et al. 1986). The rental value of 1 AUM was set at $24 (Johnson and Miller 1997).

At 1.48 AUM/ha (0.6 AUM/ac) initial stocking rate, it is assumed that actual animal consumption could equal 212 kg/ha (468 lb/ac), provided the site was in 100% range condition. However, the sites estimated range condition of 75% was used. This can be adjusted to 88% range condition for calculating sustainable harvest under Nebraska recommendations (Waller et al. 1986). So the value of grazing on the study site at 0.0% eastern redcedar canopy coverage was estimated as:

(1.48 AUM/ha) (0.88) ($24/AUM) = $31.31/ha

After eastern redcedar canopy coverage had been calculated as described at appropriate times under the 5 management options, the grazing value for a given year could be calculated by multiplying the full production potential by the percentage of open area remaining. For example:

($31.31/ha) (0.73 open area) = $22.86/ha

or $9.25/ac. This approach is justified by research results that found that while usable forage production within an eastern redcedar's canopy dripline is essentially zero, there is little or no loss of production outside of the dripline (Engle et al. 1987, Smith and Stubbendieck 1990).

The net present values of returns from the 4 action options were individually compared to returns from the no-action option. The first step was to find the differences in the respective gross grazing returns at the $24/AUM rental rate based on the projected remaining open areas of grassland. For the 4 action options, fire and herbicide application costs were subtracted from the gross returns in the appropriate years.

These control costs were based on recent Nebraska research conducted on the same study site (Ortmann 1995, Ortmann et al. 1996, Ortmann et al. 1998). This research reported a $4.96/ha ($2.01/ac) cost to conduct a prescribed fire with techniques commonly used in the Loess Hills. No costs for grazing deferment to accumulate fine fuels was assumed. The cost for supplemental Tordon 22K treatment of trees < 3 m (9.8 ft) tall surviving the initial fire was found to be about $12.36/ha ($5/ac) at the 2 ml/m (3.3/ft) rate. Further, it was assumed that 176 newly recruited trees < 1 m (3.3 ft) tall would survive each subsequent maintenance fire on an 8-year return interval, and 66 such trees would survive on a 4-year fire-return interval. These trees also were treated with Tordon 22K at 2 ml each in the 2 fire-plus Tordon options. If Tordon 22K is priced at $21.21/L ($80/gallon), herbicide costs for maintenance treatments are $7.39/ha ($2.99/ac) and $2.77/ha ($1.12/ac) for 8- and 4-year fire-return intervals, respectively. In addition, if labor is valued at $10/hr, and 34 min/ha (14 min/ac) are required for herbicide application (Ortmann et al. 1998), total maintenance herbicide application costs are $13.06/ha and $8.44/ha ($5.29/ac and $3.42/ac) for treatment every 8 or 4 years, respectively. Although surviving trees may have some potential salvage value, it is highly speculative and difficult to quantify. Therefore, in determining profitability of eastern redcedar control, we assigned no value to the trees.

Annual net revenues were calculated by subtracting initial and maintenance treatment costs from the estimated gross grazing revenues in the appropriate years. Annual net revenues then were discounted annually over 24 years at real interest rates of 8%, 6%, and 4%, a 2-percentage-point reduction having been allowed to adjust for a presumed 2%-inflation rate. The discounting function used was the standard:

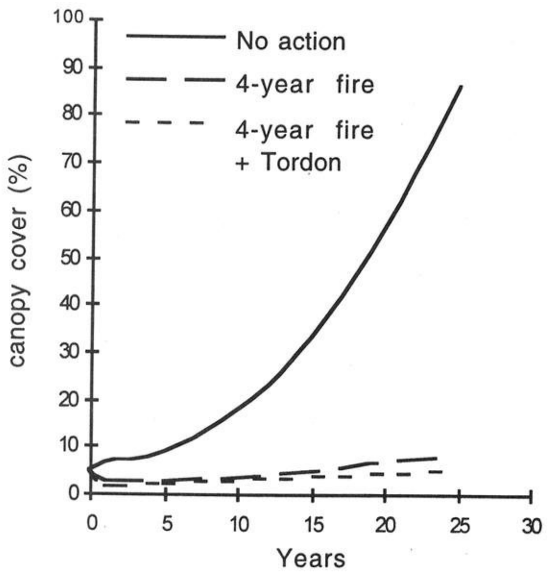
$$\sum D_i / (1+r)^i$$

where D_i = the net difference in returns from the options under comparison in year i, r = the real interest rate, and i = the year in question, the result being the net present value for each of the 4 action options.

RESULTS AND DISCUSSION

Canopy Projections

Two striking trends emerged from the canopy-expansion projection (Fig. 1): first, the accelerating speed with which the no-action option will permit nearly 100% canopy cover to develop; second, the negligible differences between the 2 fire-only options, and between the 2 fire-plus-herbicide options (Table 1). In the no-action case, it is apparent that most of the projected canopy cover after 24 years will result from a combination of trees initially < 3 m (9.8 ft) tall and from new trees recruited during the period. On the other hand, these are the trees that experience relatively high mortality in both the initial and maintenance fires at either return interval, or were eliminated under the 2 fire-plus-herbicide options. With their contribution either reduced or eliminated, canopy expansion is limited mostly to trees that initially were > 3 m (9.8 ft) tall. A simple exercise in geometry illustrates why this effect is so pronounced. For example, a tree that is initially 24 years old has a calculated area of 4.0 m^2 (43 ft^2). After 24 more years have passed, its calculated area is 22.44 m^2 (241 ft^2), a 460% increase. However, a tree that is 4 years old initially has a calculated area of only 0.11 m^2 (1.2 ft^2). After 24 years this increases to 8.48 m^2 (91.2 ft^2). This is an increase of more than 7,600%, or more than 16 times that of the larger tree. When this rate of increase is combined with the fact that the initial population of trees > 3 m (9.8 ft) tall was only 250, while the population of trees < 3 m (9.8 ft) tall plus newly recruited trees numbers nearly 10,000 on a mere 6.6 ha (16.3 ac), it



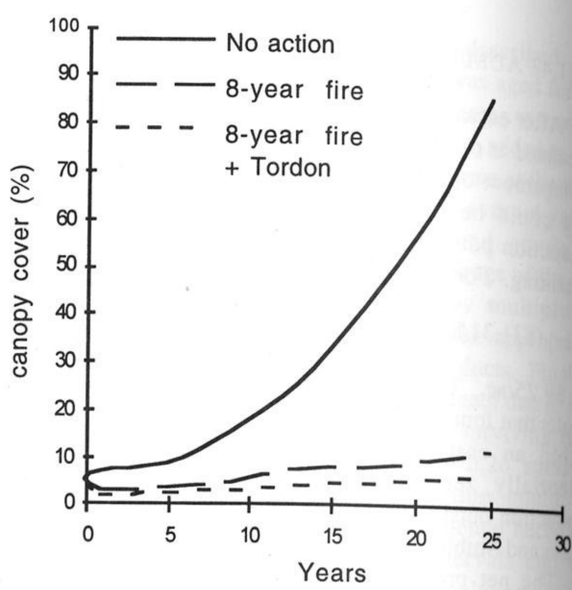


Fig. 1. Eastern redcedar canopy-expansion projections, showing the no-action option compared to 4–year treatments (left) and 8-year treatments (right).

is clear that numbers and growth potential rather than initial size are the primary sources of future canopy expansion.

Economic Analysis

Net Present Value analyses results are simple to interpret. Any positive number indicates a profitable investment at the given interest rate. Results for all 4 action options at all 3 interest rates were positive (Table 2), suggesting that some level of control is justified for most reasonable levels of time preference for money. The largest number then indicates the relatively best option. These results closely correspond to the biological results presented in Fig. 1. There is essentially no difference in the discounted returns from either the 8- or 4-year fire-only options at any interest rate. Although the 4-year fire interval performs slightly better in terms of tree control, the NPV analysis shows that the extra and earlier expense is not justified. In addition, the fire-only options uniformly perform much better economically than either of the 2 fire-plus-Tordon options at all 3 interest rates. Fig. 1 shows that while the fire-plus-Tordon options offer slightly better tree control than fire alone, the extra investment is mostly wasted.

The results then point to either the 8- or 4-year-return fire-only options. In deciding between them, some additional unquantifiable but real costs must be considered. Conducting any prescribed fire involves some degree of risk, the greatest being that of the fire escaping onto other property where damage may result. The 8-year-return option involves a total of 4 fires in 24 years, while the 4-year-return option requires 7. Thus 3 fires are eliminated, along with

Table 1. Contributions of eastern redcedar trees existing in year 0 and trees recruited during the 24-year period to percentage total site canopy coverage. Cumulative sums are shown in parenthesis.

Management option	Tree height class (m)				
	New	< 1	1 - 2	2 - 3	> 3
No action	19.4	31.8 (51.2)	17.7 (68.9)	7.6 (76.5)	9.3 (85.8)
8-year fire only	0.4	0.5 (0.9)	2.1 (3.0)	2.8 (5.8)	6.1 (11.9)
8-year fire + Tordon	0.0	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	6.1 (6.1)
4-year fire only	0.0	0.0 (0.0)	0.7 (0.7)	1.9 (2.6)	5.4 (8.0)
8-year fire + Tordon	0.0	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	5.2 (5.2)

Table 2. Net Present Value analysis results of the 4 action management options.

Real interest rate (%)	Management option a ($)			
	2	3	4	5
8	48	38	47	26
6	66	57	66	42
4	93	83	94	66

their attendant risks. The 4-year-return interval offers only slightly better control, which is largely a function of the fact that about 8 years are required for an eastern redcedar on this site to reach 1 m (3.3 ft) in height, before which it has little chance of surviving fire. So economic returns, control effects from fire, and risk reduction all point toward fire alone every 8 years as the best maintenance option. However, fires could be conducted more frequently at little additional cost if risks on a given site are acceptable.

Several other points should be noted under the heading of economics. The most important is that the NPV results shown actually are very conservative because much additional benefit will accrue after 24 years if the practice of periodic maintenance fires is continued. Under continued maintenance, canopy coverage will continue to increase only very slowly, while under the no-action option the grassland resource has been virtually lost by year 24. Consequently, the annual difference in gross returns will remain large.

Finally, it also is worth noting that this management approach has selected out and allowed to remain in place mainly trees that initially were >3 m (9.8 ft) tall. Not only will these trees continue to offer some benefits to wildlife and livestock, but these larger trees can continue to grow at low density. These are the trees in the initial population that will most quickly reach a size that will provide any possible forest-product returns. If the larger trees are selectively harvested over time rather than merely destroyed in place, they could in essence pay for their own removal.

CONCLUSIONS

The state-and-transition ecological model includes the phenomenon of state transitions when a formerly stable ecosystem type converts to another type as the result of some disruption in the original controlling factors (Friedel 1991). The management danger inherent in state transitions is that once the state boundary has been crossed, the system is unlikely to revert to its original state without a profound natural event (such as prolonged drought followed by catastrophic wildfire, or more massive and expensive management inputs). It is clear that the boundary would be crossed somewhere on the no-action curve (Fig. 1) as it progresses from about 5% to 86% canopy coverage. After this point, restoring grassland productivity and ecological values would require more intensive methods, possibly including chaining on less steep areas, or summer fire, perhaps with aerial preapplications of broad-spectrum herbicides to increase fire intensity (Scifres et al. 1976, Engle et al. 1988). Such methods may further damage the remnant grassland system as well, requiring additional expense for restoration methods such as seeding, or the use of careful low-impact management while natural successionary processes operate over years or decades.

The inevitability of ecosystem state change under this scenario indicates that time is of the essence in managing Loess Hills native grasslands. While most sites still are in the grassland state, preservation mostly through the mere return of fire to the system will suffice. Soon, however, more and more areas will pass the point of no practical or easy return. Additionally, the concept of economic threshold of infestation is irrelevant to making management decisions regarding eastern redcedar control on grasslands. Economic thresholds are useful in crop production to determine when the returns from pest treatment will exceed costs. However, because in the case infestations can only get worse, and treatment is most effective and economical at earlier stages of the progression, waiting to initiate treatment is a management error.

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FIRE TEMPERATURE DYNAMICS IN GRASSLANDS OF THE EASTERN GREAT PLAINS

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Abstract: This study was undertaken to determine the dynamics of temperatures in Iowa grassfires using a field based approach. Five representative grassfires were instrumented and monitored with dataloggers and thermocouple sensor arrays to determine the pre- and postfire thermal characteristics. The burns were conducted in varying terrain and at different times of the year to represent the range of conditions present in Iowa grassland communities. Maximum temperatures occurred at the surface ant at 0.75 meter (29") above the surface, with the cooler fires more likely to have a maxima at the surface and a longer residence time. The maximum fire temperature recorded was 875°C (1606°F). In only one location did the subsurface temperature reach a temperature lethal to plants and seeds. A consistent pattern of short term subsurface temperature decreases were also recorded during every fire. The maximum recorded decrease from ambient temperature was 5°C (9°F). These fires were all prescribed, with environmental conditions within prescription parameters. These measurements provide a picture of aboveground and belowground temperatures and residence times, giving land managers a useful tool to predict the true potential effects on flora and fauna, as well as potential physical effects to soils.

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Key words: datalogger, dynamics of temperature, grassfires, prescribed burn, thermal characteristics, thermocouple sensor array.

Daubenmire (1978:128), described the eastern region of the Great Plains as, "...a fire maintained grassland in a forest climate...." Most researchers agree that tallgrass prairie, particularly the eastern region, is maintained by fire (Gleason 1913, Daubenmire 1978:128, Wright and Bailey 1982:100, Pyne 1984:248, Higgins 1986, Ewing and Engle 1988). Historical accounts indicate that humans were responsible for many, if not most, of the fires on the Great Plains (Pyne 1982:84; Wright and Bailey 1982:80, Higgins 1986). However, anthropogenic changes in the fire cycle and fragmentation of the biome itself over the last 200 years make it difficult to determine the full impact of fire in the tallgrass prairie (Wright and Bailey 1982:81, Pyne 1984:248, Higgins 1986). Despite our limited understanding of the impacts of fire, it has become an accepted tool for natural area management.

To determine the role of fire in a particular community, the characteristics of the fires most likely to burn in the area must be studied. The tallgrass region includes a variety of fire-adapted ecosystems, which differ in specific vegetative associations and microclimate, making it difficult to extrapolate fire effects from one system to another.

The issues of temperature and heat transfer during a fire have been the subject of considerable attention in the scientific literature, although there is little emperical data on grassfire temperatures, particularly in the tallgrass region. Measuring changes in temperature and heat flux in the field can be frustrating and misleading. In a laboratory, to some degree, it is possible to regulate the components of fire and obtain accurate measurements; in the field, combinations of variables cause important characteristics of wildfire that cannot be completely duplicated in a laboratory. Variations within a wildfire can be quite large, and the exact location of expected extremes can be difficult to predict. Such variables include soil moisture, soil texture, organic content of soil, fuel load, fuel moisture, fuel depth, slope, slope aspect, fuel type, wind speed, ambient temperature, relative humidity, and numerous other factors.

A grassfire is a surface fire only, generally characterized by burning with high intensity and a fast rate of spread (Pyne 1984:117). Dry grass is a unique fuel which is 100% available; even with a short residence time a fire can burn 100% of the fuel. The small diameter, high surface to volume ratio, and low bulk density make grass quickly responsive to heat transfer. Frandsen (1973), Albini (1980), and Peter (1992) found that fine fuels (diameter < 1 mm) are heated uniformly during the preheating stage, so conduction is not a major contributor to the process.

This lack of a temperature gradient through a piece of fine fuel allows for more complete and faster combustion, and at a lower temperature, producing "flashy" fuel and thermographs. The flashiness is characteristic in grassfires.

In a grassfire, heat is transferred to soil by 3 mechanisms: convection, radiation, and conduction. Radiation and convection provide most of the heating which carries the fire (Peter 1992). Convection occurs in all fires and is a cycle of air movement in which the heat from a fire creates circulation cells which drive dry, hot air in front of the flames. Radiation, also present in all fires, is most effective in a very intense fire. Conduction is dependent upon the surface to volume ratio and the conductivity of the fuel and does not contribute greatly to the dynamics of grassfires (Albini 1980, Peter 1992).

The delay time is the time needed for fuel to be heated up to the ignition point and is critical to the speed of spread of a fire. Fires will move fastest uphill and before a wind because both of these conditions decrease the delay time by decreasing the distance between the flame/heat and the fuel (Pyne 1984:14, Albini 1980). If conditions are good for burning, more heat is transferred to the fuel ahead of the fire than is needed for combustion, so the fire picks up speed and intensity.

Numerous experiments have shown that little of the heat generated by a fire penetrates downwards (Wright and Bailey 1982:11, Pyne 1984:186, Ingersoll 1988, Peter 1992). Even intense fires, such as those in chaparral, have as little as 8% of their total heat flux downwards (Hungerford et al. 1990). Wright and Bailey (1982:11) found that in a grassfire, even with flames greater than 3.7 meters (12 ft) high, temperatures only reach 175°C (347°F) at a depth of 1.5 cm (0.6 in). Marked temperature rises occurred only to a depth of 1 cm (0.25 in). In laboratory fires with a residence time of almost 20 min, the downward heat pulse penetrates less than 100°C (212°F) at only 5 centimeters (2 in).

During any wild or prescribed fire, a temperature gradient develops downwards (Hungerford et al. 1990). The sharpness of the gradient depends on the characteristics of both the soil and the fire. Peter (1992) showed that characteristics such as the amount of convective heat, and the distance of the surface from a radiant heat source, would have a measurable effect on heat penetration downward. Steward et al. (1989) used the intensity and duration of fire as primary parameters for determining depth of heat transfer, and they point out that it is essential to continue to monitor subsurface temperatures for a period after the fire passes because subsurface temperatures often continue to rise even while surface temperatures are decreasing.

Both Peters (1992) and Hungerford et al. (1990) found that the presence of duff will affect downward heat flow. Dry duff acts as a conductor, contributing significant heat to the soil. Moist duff acts as an insulator to prevent a significant amount of heat from penetrating, because heat is used up in the vaporization of the water. If duff, either dry or moist does burn, and is consumed down to the mineral soil, residence time increases.

Wright and Bailey (1982:9-11) discussed maximum temperatures in various grassfires and speculated that the highest temperatures are associated with "...local accumulations of loosely arranged litter and intense winds...." The maximum surface temperature they found was 682°C (1259°F). Average surface temperatures for grassfires was between 102°C and 388°C (215°F and 730°F). Steward et al. (1989) conducted a series of experimental laboratory burns using fine fuels (0.25 cm) which resulted in a heating time of 25.4 seconds and produced a maximum lethal heat penetration of 6.2 cm (2.4 in). When the fuel load was decreased, lethal heat penetration also decreased.

Thermocolor pyrometers have been used to measure surface temperatures during fires (Gibson et al. 1990). These consist of ceramic tiles with dots of temperature-indicating paint on the unglazed side. Using this method, Gibson et al. (1990) found that maximum temperatures in a Kansas tallgrass prairie were 399°C (750°F), with the highest temperatures occurring where there was small woody fuel such as shrubs and small trees. Although such measurements record the highest temperatures reached during a fire, they only provide a single, static surface measurement, and they give no indication of the rate of temperature increase, residence time, or rate of temperature decline.

Several studies have used thermocouples for measuring the aboveground and belowground temperatures during a fire (Wright and Bailey 1982, Sasaki et al. 1987, Ewing and Engle 1988). The major advantages to this method are greater accuracy and a sequential temperature record of a fire event. The resulting range and residence times of the heat at different depths and heights can be compared with other factors for determining cause and effect relationships. When combined with a data input system such as a datalogger, thermocouples can provide a record of many measurements simultaneously, thus it is possible to correlate aboveground temperature dynamics with subsurface measurements. Ewing and Engle (1988) used dataloggers to sample fire temperatures at 2-sec intervals at 15 cm and 30 cm (6 in and 12 in) above the soil surface. They reported surface residence times of 10,400 ± 1900 degree seconds, based on ambient temperatures before and after the fire. Unfortunately, temperature ranges were not given.

Hungerford et al. (1990) presented data from a variety of fires, including two grassfires, 1 in California and 1 in the southern United States. In these fires, surface temperatures ranged from 93°C to 545°C (199°F to 1013°F). Temperatures at the surface did not always correlate with underlying temperatures. The grassfires were the coolest, and heat lethal to most plants was not reached even at 1 cm (< 0.5 in). Hungerford et al. (1990) pointed out that a "hot" grassfire is hot only in terms of temperature range, and the actual heat transferred may be considerably less than cooler fires which have much longer residence times. The study concluded that duration of aboveground heating is a significant factor in soil heating.

The lack of empirical data with which to test these models leads one to question why such data are so scarce. Thermocouples have been used successfully in the field for obtaining temporal and spatial heat profiles, although there are few of these in the current literature on grassfires.

Our study provides temperature data and analysis from 5 grassfires in Iowa. Measurements include the range of temperatures that occur, various heights and depths and their residence times. To measure these parameters, an array of thermocouples was set up in the path of grassfires to obtain a temporal profile of temperatures above and below ground. This methodology was repeated with grassfires in different areas, with different burning conditions, and at different times of the year in order to analyze relationships and patterns common to all the fires. A great many models already exist which predict heat transfer in soils, but none to date includes natural soil features such as live biomass and a natural moisture gradient.

MATERIALS AND METHODS

Temperature

For measuring temperatures during the fires, a standardized thermocouple array consisting of twelve chromel alumel thermocouples was used (Fig. 1). The array was connected to a Campbell 21X Datalogger. Up to 3 datalogger thermocouple arrays were used in each fire. The dataloggers were then buried, and sensor wires were run from the dataloggers to "mast" setups. For each datalogger, sensors were attached to each of 2 2.5-cm x 3.25-m (1-in x 10.5-in), hollow, galvanized steel poles at heights of 3.0 m and 0.75 m (10 ft and 2.5 ft). Each of these poles is referred to as a "mast." Surface sensors were placed at the ground surface. For subsurface sensors, a shovel was used to make a crack sufficiently wide for the sensors to be inserted into the side at the appropriate depths. The crack was then filled with loose soil and tamped down slightly. Grass, litter, and detritus were then arranged over the top to resemble as closely as possible the undisturbed site. Because this operation unavoidably left a small area of flattened fuel and bare ground, the masts were always placed upwind from the datalogger burial site.

The sensor setup was configured to provide a thermograph of a vertical cross-section. Ambient temperatures for each sensor location were determined by taking an average of the first 20 readings in a sensor data series. In this study, "residence time" refers to the length of time the temperatures were at or above 60°C (139°F) (Wright and Bailey 1982:16, Steward et al. 1989). This was to provide data specific to vegetative effects.

Data were stored on cassette tapes and downloaded and converted to Microsoft Excel format. These data were divided into separate datalogger sites labeled A, B, or C. The 2 masts of the sensor setups used for each datalogger were designated "a" and "b." Data were then fully identified by both an uppercase and a lowercase letter. Such that a label of "Ab" referred to mast "b" at datalogger site "A."

Five experimental burns were included in this project: Broken Kettle(a), Broken Kettle(b), Ely, Dudgeon, and Cedar Hills. These burn units are representative of the range of fuel and burn conditions found in Iowa grassland communities.

These 5 units include a wide range of grassland habitats in Iowa, from native prairie to planted game habitat. Burn conditions ranged from extremely poor at Broken Kettle(a), to excellent at Ely. Terrain ranged from the steep topography in the loess hills, to flat areas in east-central Iowa. A more detailed discussion of each burn unit follows.

Broken Kettle(a) Burn Unit

Broken Kettle Grasslands is a 2000-acre preserve owned by The Nature Conservancy and located in the Loess Hills, 11 miles north of Sioux City, Iowa. This burn was conducted on 6 August 1996. The unit was about 30 acres and vegetation consisted primarily of brome (*Bromus* spp.), big bluestem

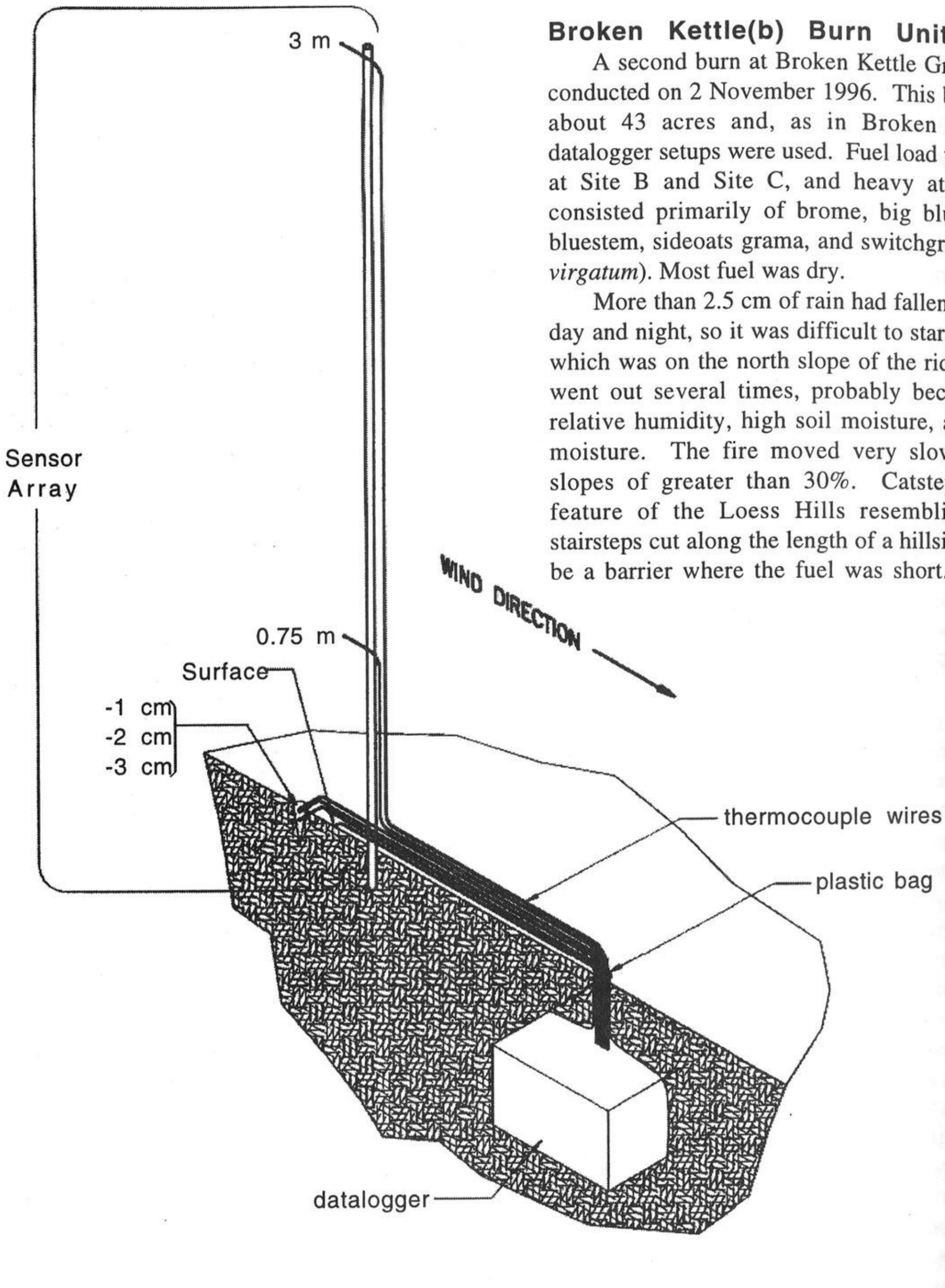

Fig. 1. Instrumentation for temperature measurement in fires.

(*Andropogon gerardii*), little bluestem (*Andropogon* [*Schizachyrium*] *scoparium*), and sideoats grama (*Bouteloua curti-pendula*). The majority of the fuel was 15-30 cm high, thick, and green. The tallest fuels were dry, but sparse. Forbs were also present, but the sensors were set up in sites dominated by grasses. Three sites (A, B, and C) were set up with two masts and 1 datalogger at each.

Broken Kettle(b) Burn Unit

A second burn at Broken Kettle Grasslands was conducted on 2 November 1996. This burn unit was about 43 acres and, as in Broken Kettle(a), 3 datalogger setups were used. Fuel load was moderate at Site B and Site C, and heavy at Site A. It consisted primarily of brome, big bluestem, little bluestem, sideoats grama, and switchgrass (*Panicum virgatum*). Most fuel was dry.

More than 2.5 cm of rain had fallen the previous day and night, so it was difficult to start the backfire which was on the north slope of the ridge. The fire went out several times, probably because of high relative humidity, high soil moisture, and high fuel moisture. The fire moved very slowly, even up slopes of greater than 30%. Catsteps, a typical feature of the Loess Hills resembling irregular stairsteps cut along the length of a hillside, proved to be a barrier where the fuel was short. In the area around Site A, the fire smoldered past on the surface, leaving most of the approximately 30-cm high green fuel slightly withered, but standing. Flames ranged from about 1.0 cm to a little over 1.0 m high.

Ely Burn Unit

This 20-acre unit, located in northern Johnson County, Iowa, about 1.5 km south of Ely, is owned by the U. S. Army Corps of Engineers. It was burned on 2 April 1997. Vegetation consisted of mixed brome, Indian grass (*Sorghastrum nutans*), and switchgrass with a variety of forbs. Fuel depth was 0.5-1.5 m, and fuel load was fairly uniform. One datalogger setup was used. This fire burned fast and hot, although the head fire which burned through the sensors had only about 12 m (40 ft) to pick up intensity before reaching them. Flames near the sensors were about 2-3 meters (6-10 ft) long, whereas in other areas they reached 6-7 m (20-23 ft).

Dudgeon Lakes Recreation Area Burn Unit

Dudgeon Recreation Area is managed by the Iowa Department of Natural Resources, and is located in northern Benton County, about 3 km north of Vinton. The area for this burn was a rectangular field of about 15 acres of sandy floodplain. The vegetation consisted primarily of switchgrass, with some dropseed (*Sporabalus* spp.); few forbs were observed. This field was surrounded by deciduous forest on all sides. Two arrays were set up, in the approximate center of the field. Most of the fuel was dry.

Cedar Hills Burn Unit

Cedar Hills Sand Prairie is a 60-acre tract of reconstructed and restored tallgrass prairie owned and managed by The Nature Conservancy. It is located in Black Hawk County, Iowa, about 16 km northwest of Cedar Falls. The burn unit was about 8 acres along the eastern border of the preserve. Vegetation consisted of a variety of forbs and grasses, but the sensors were both set in areas dominated by little bluestem. Two datalogger setups were used, both set up in the south central region of the burn area.

RESULTS

The 5 fires reflected a wide range of conditions and they ranged from fast and hot, to slow and cool. The Ely and Dudgeon fires were very hot, very intense, and burned quickly; both locations had ideal fuel (tall, thick, and dry). The Broken Kettle(b) site also contained high fuel loads and burned hot, but because there was little wind and ambient temperatures were low, the rate of progress of the fire was relatively slow. The Cedar Hills fire was cooler, slower, and generally a less intense fire. Broken Kettle(a) was by far the coolest fire.

The data collected in this study are presented in the form of thermographs. These are line graphs which allow the temperature dynamics of the fire to be observed.

Broken Kettle(a)

The thermographs from the site at the Broken Kettle(a) burn are divided into: a) a 4-min period when the effects of the approaching fire were first apparent and b) a 7-min period when the fire was actively burning through the sensors (Fig. 2). The break in the graph represents 13 min of little change before the fire burned through the sensors. The readings from 0.75 m (2.5 ft) and 3 m (10 ft) reflect the increase of temperature variation almost 20 min before the fire actually reached the sensors. The fire approached this sensor from the downhill side, and was also burning below the sensors on the southwest, west, and northwest sides of the slope before it reached the sensors. As indicated by the thermographs, the soil at all depths began to heat up before the fire was very close. At Site A, the fire burned over the sensors which were on the surface underneath some green fuel which did not burn. These sensors recorded the coolest surface temperature of any of the fires. By contrast, Site C from the same fire had a southwestern aspect, was on the shoulder of the ridge, and had taller, drier, fuel. Fuel consumption in this area was 100%.

Broken Kettle(b)

There are only 4 complete thermographs from the Broken Kettle(b) burn. Some patterns were characteristic of the time of year. For example, aboveground locations were cooler than the subsurface locations both before and after the fire. Another seasonal pattern was indicated by the speed with which aboveground sensors cooled off, particularly at the headfire locations which did not burn until almost sunset when the ambient temperature was dropping rapidly.

Ely

The B mast at Ely showed the sharpest drop in subsurface temperature of all the fires: 5.62°C (10.12°F) in 3 seconds at -1 cm.

Dudgeon

The Dudgeon fire burned very hot and fast with flames of 3-6 m (10-20 ft) long, a big column of smoke, and weak fire whirls. Data from this fire include the highest temperatures found in this study. The sensors had been fastened to the masts with masking tape wrapped about 1 cm thick (Fig. 3). After the fire, 1 of the 3-meter (10-ft) sensors was laying on the ground about 1.5 m (5 ft) from the mast and there was no sign of any tape. The slow cooling off period is shown on the thermograph,

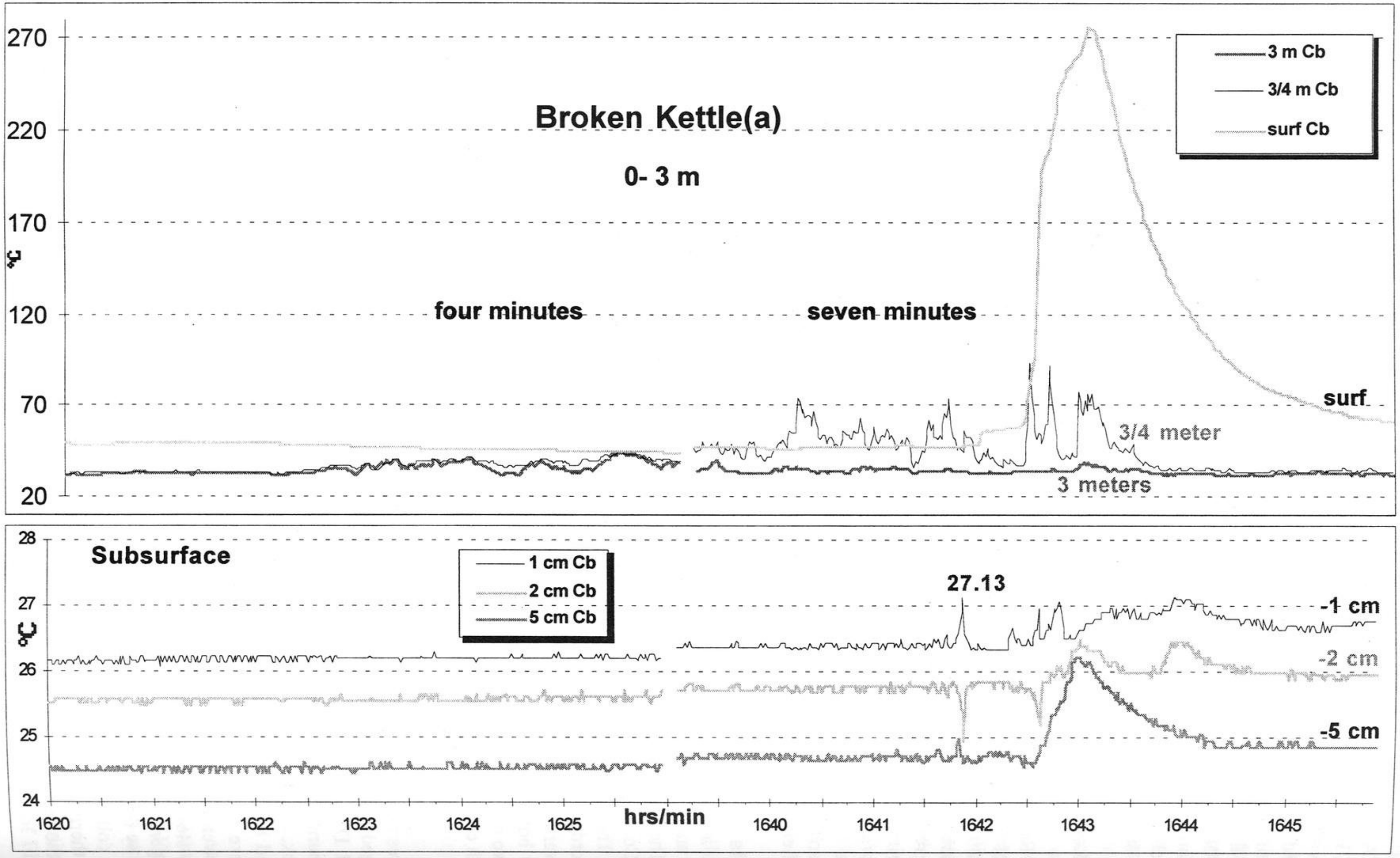

Fig. 2. Thermograph from Broken Kettle(a).

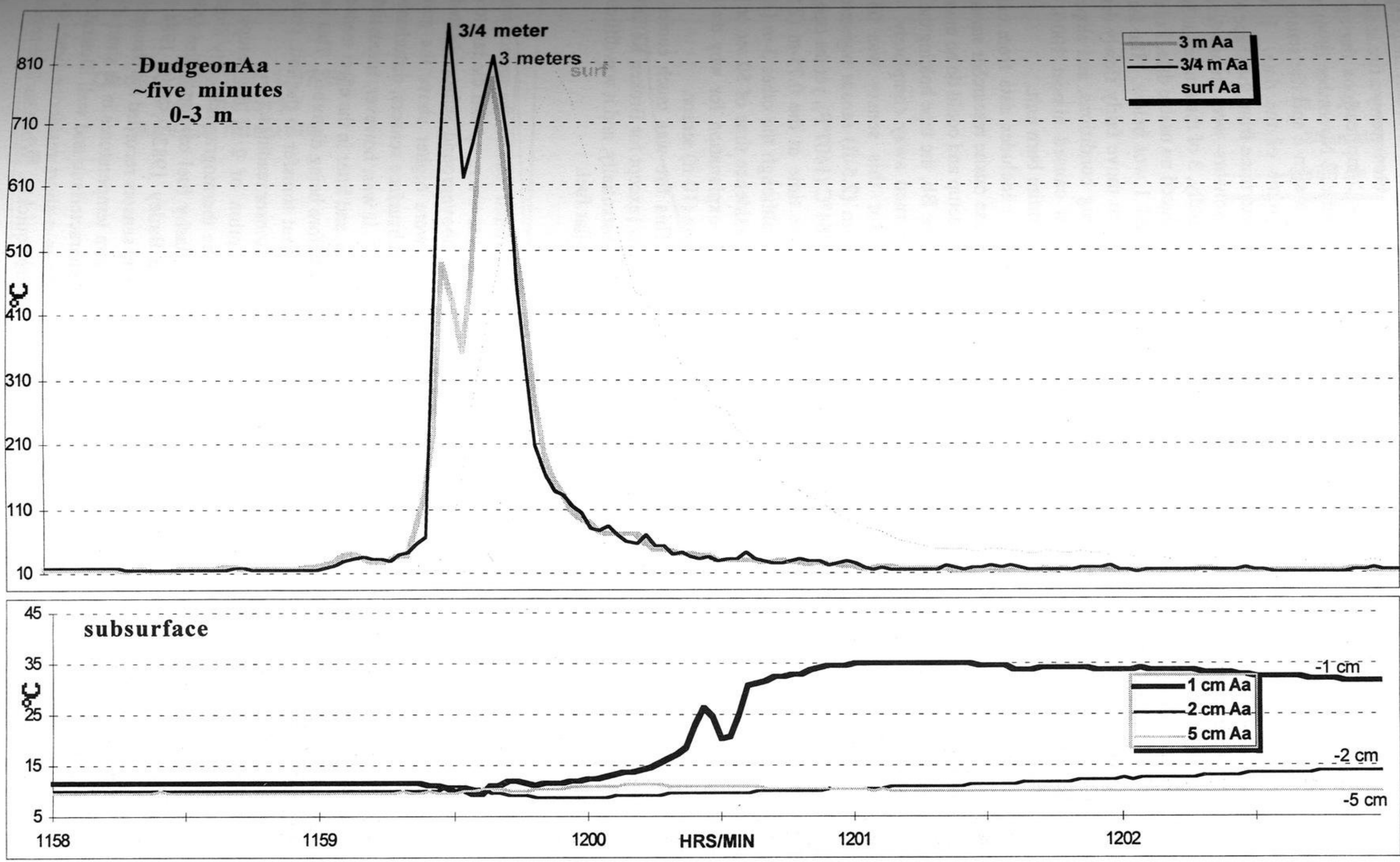

Fig. 3. Thermograph from Dudgeon

although it is not clear at what point the sensor fell. The reading for 3 m (10 ft) at this site for the Dudgeon fire was not included in the correlations.

Comparisons Between Fires

As a measure of how hot each fire was, the maximum temperatures from the sites at each burn unit were averaged. These temperatures ranged from an average maximum temperature of 787°C (1449°F) at Dudgeon to 109°C (228°F) at Broken Kettle(a). Peak temperatures recorded ranged from 875°C (1601°F) at the Dudgeon fire, to 276°C (529°F) at Broken Kettle(a) (Fig. 2 and Fig. 3). Maximum temperatures occurred at the soil surface at 12 of 18 sites; and at 0.75 m (2.5 ft) at 5 of 18 sites In the hottest fire, Dudgeon, maximum temperatures all occurred at 0.75 meters (2.5 ft). The second hottest fire, Ely, had 1 of the 2 maxima at 0.75 m (2.5 ft), and 1 at -1 cm. However, the -1 cm sensor was dislodged before the fire, and was not used in these correlations. Lethal heat occurred at the surface 90% of the time; at -1 cm 9%; at -2 cm 5%; and not at all at -5 cm. For the coolest fires, Cedar Hills and Broken Kettle(a), maximum temperatures were all at the surface (Fig. 4).

At every surface location in every fire except the Broken Kettle(a) fire 100°C (212°F) was reached. In this fire, 100°C (212°F) was only reached by 2 of the 6 surface sensors, both at Site C.

In all cases except for the Broken Kettle(a), the dry/green fuel ratio was high, and the time from ambient temperature to maximum was short. In the Broken Kettle(a) fire, maximum time from ambient temperature to maximum temperature at the surface was 1377 sec, an increase of only 0.04°C/sec (0.072°F/sec). By contrast, among all the other fires, the longest time from ambient to maximum temperatures at the surface was 188 seconds. The shortest time to go from ambient to maximum at the surface was 60 sec. This was found at 3 locations for an average temperature increase of 437°C (786.6). The fastest rates of increase were at 0.75 m (2.5 ft) at 20°C/sec and 29°C/sec (36°F/sec and 52°F/sec), both at Dudgeon. The fastest surface rate of increase was 8°C/sec (14°F/sec), at both Dudgeon and Cedar Hills. With 2 exceptions, the maximum temperature at –5 cm (2 in) occurred at least 16 min after the surface had reached its maximum.

DISCUSSION AND INTERPRETATION

Fire Specific Observations

Broken Kettle(a).—The extended preheating period may be a feature of slow burns, particularly on a hill or with a slight wind, and it may help explain why such green fuel was able to carry a fire at all.

Broken Kettle(b)—. Complications during this fourth burn (Broken Kettle, 2 November 1996) made it speculative to try to assign a specific sensor to a specific channel for some of the data. It was, however, possible to determine from the shape of the thermographs which sensors were subsurface or aboveground. Additionally, 3 of the sensors at Site B malfunctioned and produced no usable data, 2 of these were aboveground, and 1 was below. The lack of wind allowed the fire to move fairly slowly despite good fuel, good burning conditions, and slopes in excess of 35%. This caused almost 100% fuel consumption over the entire burn unit.

Ely—. The Ely fire includes data from only 1 datalogger setup because onsite researcher strained a calf muscle during the setup and could do no more.

Dudgeon—. At Site Bb, the tape holding the 3-m (10-ft) sensor was burned away completely. The maximum reading for this sensor was 661°C (1222°F). The 0.75-m (2.5-ft) sensor registered a high temperature of 764°C (1407°F), yet the tape was intact. The residence time at the 0.75-m (2.5-ft) sensor was 184 sec, although the other 3-m (10-ft) sensors measured a residence time of 50 sec or less. There is no obvious explanation for why the tape only burned off the 3-m (10-ft) sensor.

Cedar Hills—. This fire was much cooler and slower than the others [except for Broken Kettle (a)]. Vegetation varied substantially, and it was difficult to find 2 areas with similar fuel.

Temperature

Of the 3 aboveground sensors, the surface sensors were usually the last to warm up and the last to cool down. Typically, aboveground sensors heated up sooner when they were higher above the ground. While placing the subsurface sensors, disturbance to fuel was minimized. It was, however, impossible to replace duff, detritus, and litter in the exact manner in which it had been before being disturbed. This would have an effect on heat transfer to the soil, possibly affecting subsurface sensor readings.

With the exception of 2 of the setups from Broken Kettle(a), the thermographs clearly illustrate the characteristic flashy fuel of a grassfire (Albini 1980, Wright and Bailey 1982:9; Pyne 1984:115-116). Aboveground sensors recorded the change from ambient to maximum temperatures in as short a time as 60 sec. Also characteristic and well illustrated by the thermographs is a short residence time, as the fuels are incinerated quickly. When surface residence

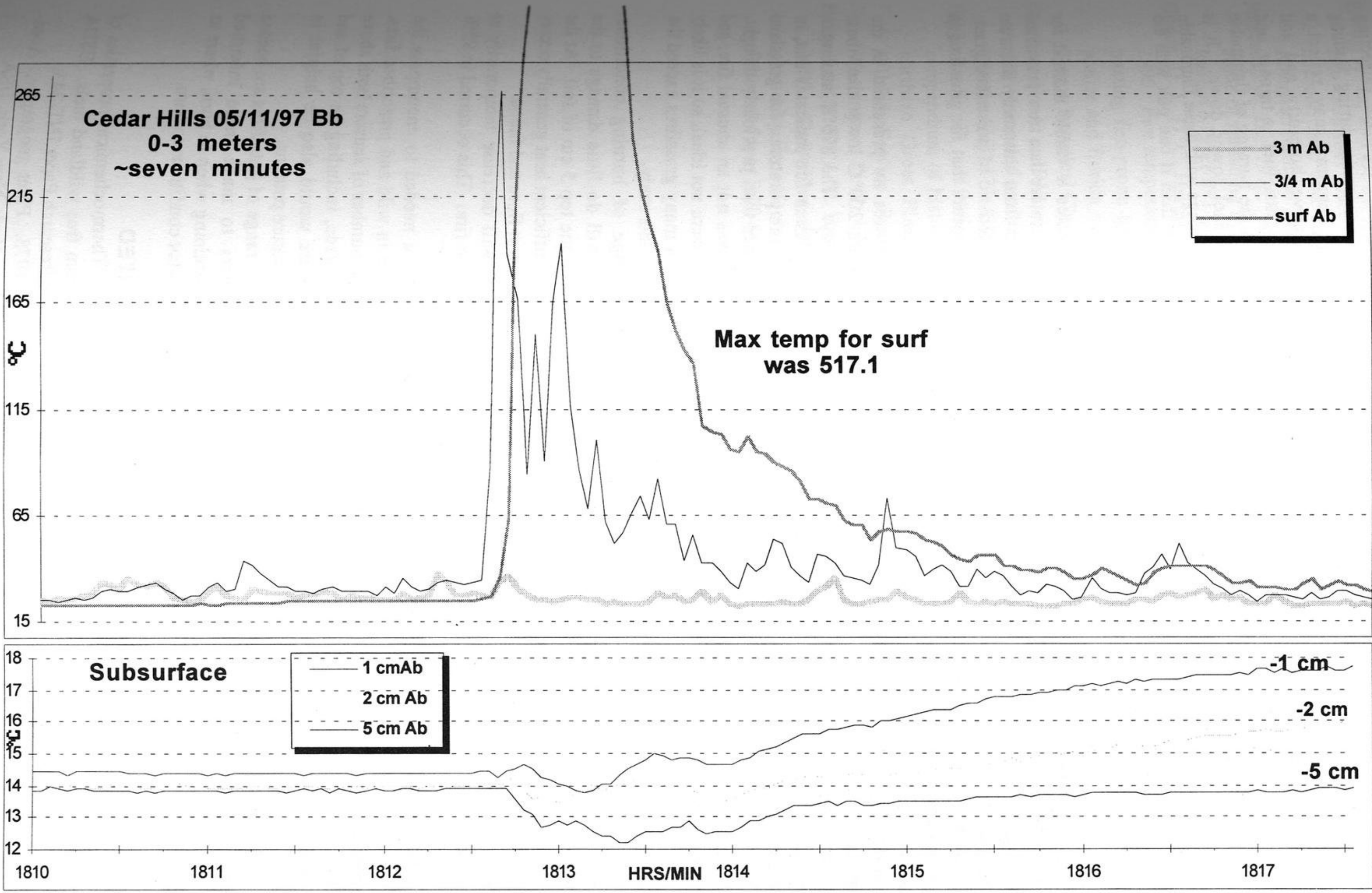

Fig. 4. Thermograph from Cedar Hills

times are graphed with maximum temperatures, there appears to be an inverse relationship, with longer residence times paired with hotter fires.

Wright and Bailey's (1982:9) discussion sets the average surface temperature for grassland fires between 102°C and 388°C (216°F and 730°F), with a maximum measured temperature of 682°C (1,259°F). The average of Dudgeon, Ely, Cedar Hills, and Broken Kettle(a) fires was 403°C (757°F). The only reason the fire burned through all the sensors during the Broken Kettle(a) fire was because it was relit close to the sensors, so it is questionable whether these data should be included as data from a typical burn. Excluding the Broken Kettle(a) fire, the average surface temperature was 502°C (935°F). The maximum temperature recorded in this series of fires was 875°C (1,606°F). Since the fires used in this study were not extraordinary, it further suggests the need for more of the type of data this study provided.

An important aspect of this study was an examination of the depth of lethal heat penetration. A low estimate for this was 60°C (140°F), and was found to have occurred in only 3 instances, none of which was deeper than 2 cm. This penetration is significantly less than was found by Steward et al. (1989), despite longer heating time. In the Ely fire, heating time was 141 seconds and lethal heat penetrated to -2 cm (< 1 in). However, Steward et al. (1989) recorded a heating time of only 25.4 sec for lethal heat to reach 6.2 cm (2.5 in). In both cases, sand was a major component of the soil, but a significant difference was moisture. Steward et al. (1989) did not include moisture as a parameter in their experiments, while soil moisture at the Ely location was 21.5%, by weight. Another factor which may have contributed to this difference is the higher density of fuel used by Steward et al. (1989); they used wooden dowels which, although they were comparable in diameter to grass stems, were more dense and not comparable to grass leaves.

Our study found much shorter surface residence times than Ewing and Engle (1988). Although Ewing and Engle used ambient temperatures to determine residence time and we used 60°C (140°F), even multiplying residence times found here by 100, residence times differ by more than 1 hr. This provides further evidence of the variability of grass-fires.

The lack of a significant correlation between surface and subsurface temperatures may be due to the presence of fuel at the surface which provides an immediate and extreme source of heat. Because dry grass burns so quickly, there is little time for subsurface soil moisture to vaporize, affecting maximum temperatures occurring during flaming combustion. The high maxima may reflect a correlation between relative humidity and soil moisture. At greater heights, fuel is thinner, and most of the heat results in the burning of flammable gasses volitilized from fuel lower down. It is possible that ambient air mixes with these flammable gasses to a greater degree than it can mix with the solid fuel at the surface.

CONCLUSIONS

This study demonstrates a viable method for obtaining field-based temperature data from prescribed grassfires. Data obtained from this study illustrate thermal dynamics characteristic of prescribed grass-fires. In particular, it appears that for grassfires in Iowa :

1) Maximum temperatures as presented in the current literature are 200°C lower than those recorded in this study. The 875°C maximum recorded at the Dudgeon fire indicates that, in general, maximum temperatures for grassland fires are much greater than previously thought. The Dudgeon fire was not an unusual fire, and burning conditions were not ideal, so it is likely that temperatures in many grassfires exceed the maxima recorded in this study.
2) With a wide range of burning conditions, prescription fires will do little damage to the biomass located in the top 5 cm of soil. At the surface, however, sufficient heat generally occurs to damage or kill most flora and fauna.
3) Soil temperature will decrease temporarily at some point during a fire. This occurred in 95% of the samples.
4) More field data are needed to encompass the variability inherent in wild and prescribed fires. An increase in the number of sensors both above and below the surface, including on top of and beneath duff layers would also be helpful in determining temperature patterns.
5) Data from a wider range of grassfires are needed by land managers to make more informed decisions in determining when to burn, where to burn, and under what conditions to burn.

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SIMULATED GRAZING AND HAYING EFFECTS ON A MIXED GRASS PRAIRIE

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Abstract: We wanted to determine the influences of litter removal, defoliation, and topography on the productivity and species diversity of a natural grassland. The first manipulation was litter removal to simulate the biomass removal effects that modern haying implements have on grasslands. The manipulation was carried out by removing all the biomass littering the ground in the sample sites. The next manipulation simulated the grazing action of large herbivores by pruning the sample plots to prescribed heights. The defoliated plots were pruned to either 20 cm, 30 cm, 40 cm, or 50 cm. Topography was studied by comparing mean regrowth masses for samples at different topographic locations on a hillside. Comparing biomass produced at the upland sites, to those sidehill sites, to bottom sites showed that bottoms were the most productive. Comparing biomass produced at different clipping levels showed that the more intense the clipping (20 cm) the more productive the site. We determined that removal of litter from the bottoms lowered the grass/forb ration the greatest.

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Key words: defoliation, grass/forb ratio, grassland species diversity, litter removal, productivity, topography.

Native prairie supports most of Nebraska's cattle production, at least through part of the year. Major economic advances have come about through management strategies that enhance the productivity of natural prairies. Successfully managed grasslands are those which are manipulated in such a way as to produce the greatest amounts of harvested herbage. Grassland productivity is measured by: (1) fresh weight, (2) dry weight, (3) digestible matter, (4) weight of protein, and (5) energy (Harris 1971).

Since the mid 1800s, observations have been made on what manipulations produce the most successful grasslands. Many studies have been completed in the areas of rotational grazing, high-intensity short-duration grazing, and holistic range management by the means of controlled burning and fertilization. These studies have produced valuable results in predicting which manipulations produce the most successful grasslands.

The practice of burning in late spring rather than early spring and monitoring soil moisture levels (Anderson 1965) demonstrates the use of science in agriculture to produce successful grasslands. Native prairies are supporting larger numbers of cattle than ever before through these management practices aimed at maximizing the production and abundance of palatable and nutritious native species (Owensby and Smith 1979). Spring burning in tall-grass prairie increases productivity of dominant grasses in part by eliminating negative effects of detrital accumulation on plant growth (Knapp and Seastedt 1986). As a result, large herbivores use burned landscapes more uniformly than unburned landscapes (Hobbs et al. 1991). According to Towne and Owensby (1984), cattlemen as far back as the 1880s observed that steers gained more weight on burned rather than on unburned range. As a result, grazing leases of that time mandated annual burning.

This experiment examined the effect that the topographic location of a sample site has upon the mass of regrowth. By placing equal number of experimental plots in the bottomlands, along the sloping sides, and at the top of the hill, a comparison of mean harvested biomass at each topographic location was compared. Through a comparison of these means in a statistical manner a determination of the most productive topographic location was made.

The purpose of this experiment was to determine if a mixed grass prairie needs human manipulation in order to significantly increase the aboveground net primary production.

MATERIALS AND METHODS

Three different effects were examined: haying, grazing, and topography.

This experiment was done on the U. S. Army Corps of Engineers, Harlan County Lake project. The site was Agriculture Lease Number 126 located in Section 19, T1N, R17W, Harlan County, Nebraska. The Nebraska Soil Survey classifies this soil as Uly or Coly silt loams with 9% to 31% slope. This area was selected for its diverse land contour and its lack of human intervention over the past fifteen years.

In total, 72 different sites were examined throughout the experiment. Each experimental site consisted of a 50-cm^2 plot. These sample sites were placed along 3 different contours: 24 sites were located at the top of the hill, 24 sites along the sloping sides of the draw, and 24 sites along the valley floor that predominated the agricultural lease.

The experiment was laid out on 26 March 1997. Plots were measured and the plants in selected plots were subjected to litter removal and clipped to the prescribed heights. The regrowth of the grass and species diversity in each plot was monitored throughout the summer of 1997. Regrowth data were collected nearly a year later on 12 March 1998, when the plants in each experimental plot were defoliated to the ground. The biomass was collected into paper bags and dried for 2 weeks. Then the regrowth was weighed and the data were prepared for statistical analysis.

At each topographic location the plots were manipulated in the same ratio. The 8 control samples at each contour were left undisturbed until harvest on 12 March 1998. The other 16 sites were subjected to both the simulated grazing and haying manipulations. Eight of these 16 sites were subjected to litter removal while the detrital litter was undisturbed at the other 8. These same 16 sites were tested for the simulated graze under both litter conditions. Each of the 4 prescribed cutting heights contained 4 replicates, 2 with the litter present and 2 where the detrital litter was removed.

The removal of detrital litter was used to simulate the action of haying. We removed the litter that covered the soil in the sample plot. In the other experimental plots the detrital litter was undisturbed. This allowed for the determination of whether the litter removal would increase the above ground net regrowth.

Defoliation was used to simulate the grazing action of large herbivores. To evaluate responses of range grasses to herbage removal, removal patterns should simulate those under grazing (Strout et al. 1985). To allow for the different intensities of grazing, sites were pruned to either 20 cm, 30 cm, 40 cm, or 50 cm. The 20-cm defoliation represented high grazing intensity, while less intense defoliation represented less intense grazing schemes. The intensity of defoliation was examined to determine what pruning height would produce the most productive grassland.

The effects of the simulated haying and grazing upon the plant diversity was examined by determining a grass/forb ratio for each experimental treatment. This was done throughout the growing season.

Statistical results were compared using a Duncan Multiple Range Test which provides for a comparison between the means of selected variables. Statistical differences were determined by comparing the difference in mean regrowth weight to the Duncan Significance Value. (A statistical difference at the 5% level is suggested by a difference in mean regrowth greater than that of the Duncan Significance Value.)

RESULTS

This experiment provided a comparison between the variables: (1) litter removal, (2) defoliation height, and (3) topographic location. The results were then analyzed for harvested dry weight and plant diversity.

The amount of biomass harvested declined the higher up the hill the sites were located. However, no statistically significant difference was found due to topographic location (Table 1).

The effect of litter on the overall growth is shown in Table 2.

The effect of defoliation height on the overall growth is shown in Table 3.

Plant diversity was expressed by the grass/forb ratio (Table 4).

The plots where the litter was removed contained the lowest grass to forb ratio and a greater species diversity. A list of species present in the experimental sites can be obtained from the author.

DISCUSSION

In general, prairie management requires the removal of old litter from time to time in order to be maintained. This had been done "naturally" by recurrent fires prior to European settlement. However, much of what fire does can be done by grazing and by haying, and that is why we investigated these latter 2 parameters.

Advantages of Fire

Many of the grasslands of America and Africa owe their existence to fire, which stimulates some grasses, reduces competition from woody species, and does not deplete the organic matter of the soil (Spedding 1971). Without recurrent fires in the tallgrass prairie, litter accumulates, plant community composition changes, and woody species invade.

Table 1. Effects of topographic location on plant productivity. Although the bottom produced more growth than either the sidehill or top, the difference were not statistically significant.

Site #	Location	Mean (g)	Comparison	Differences	Duncan #	Significance
1	Bottom	168.44	(1-2)	13.342	14.15	NS
2	Side	155.10	(1-3)	13.750	14.15	NS
3	Top	154.69	(2-3)	0.408	14.15	NS

Grasslands in North America are unstable when in contact with woody vegetation; they are being invaded by forests on the east and north, and woodlands on the south and southwest (Axelrod 1985). This invasion is occurring due to the fact man has controlled or totally eliminated natural fires that at one time swept across the mid-section of North America.

Tallgrass prairies are stimulated after spring burning. This stimulation is somewhat brought about through the elimination of the negative effects of detrital accumulation on plant growth (Vinton et al. 1993). While clearing the detrital accumulation, fire does not harm tallgrass species because their growing point is near or beneath the surface and protected from all but the most extreme heat. A summary of fire studies indicated that spring burning seasonally-grazed pastures has the positive effect of increasing aboveground and belowground net primary production (Parton and Risset 1979).

Plant diversity throughout the prairie seems to increase with exposure to burning. The fire regime alone strongly influenced the grass/forb ratio, which was much higher on frequently burned prairie (2.83:1) than on the infrequently burned prairie (1:0.87) (Vinton et al. 1993).

Advantages of Haying

Haying has become the major management tool for the mixed grass prairies located on the Corps of Engineers' Harlan County Reservoir Project. The strategy is profitable for the government and does not require the man-hours or the associated risks that accommodate controlled burns. The property at one time was leased out for grazing purposes. This ended 15 years ago due to budget cuts that eliminated the maintenance positions needed to maintain fence.

Haying manipulations have been demonstrated to be as effective as fire manipulations in certain situations. Within the same soil type, mowing may even have a greater impact than burning (Gibson et al. 1993). Collins (1987) hypothesized that higher plant diversity is observed within the mowing treatments through the decrease of the competitive dominance of matrix-forming grasses. Mown plots had a higher cover of C_3 grasses, annual/biennial forbs, and a greater number of annual grasses and exotic species (Gibson et al. 1993).

Our haying manipulation showed that the removal of litter leads to enhanced regrowth. This was demonstrated by the statistically significant difference between the litter-removed plots and the control plots. The lack of significance between the litter-present-but-pruned plots and the control plots demonstrates that pruning the grass in the simulated grazing scheme did not stimulate the spring regrowth as well as removing the litter. In part, this suggests that in dry years, the plots with litter removed will get more water from precipitation than the plots with remaining litter. Heavy litter presence will act as an umbrella allowing little precipitation to come in contact with the soil where it can be taken up by the plants. The extremely dry summer of 1997 played a part in the fact that topographic location did not have a significant effect on mean regrowth. In years with

Table 2. Effects of litter on plant productivity. Comparing plots with litter removed to plots with litter present or the control were both statistically significant.

Variable	Litter	Means (g)	Comparison	Difference	Duncan #	Significance
1	Removed	175.46	(1-2)	16.73	13.45	*
2	Present	158.27	(1-3)	30.71	14.11	*
3	Control	144.75	(2-3)	13.97	14.11	NS

Table 3. Effects of defoliation height on plant productivity.

Variable	Height (cm)	Mean	Comparison	Differences	Duncan#	Significance
1	20	194.96	(1-2)	22.54	16.24	*
2	30	172.42	(1-3)	38.21	17.03	*
3	40	156.75	(1-4)	50.21	14.34	*
4	Control	144.75	(1-5)	52.12	17.72	*
5	50	142.84	(2-3)	15.66	16.24	NS
			(2-4)	27.67	13.91	*
			(2-5)	29.57	17.56	*
			(3-4)	12.00	13.26	NS
			(3-5)	13.91	17.03	NS
			(4-5)	1.91	13.26	NS

above average precipitation the lowlands would probably be in contact with more available water due to run off.

Advantages of Grazing

Grazing can increase the survival of other species, thereby increasing species diversity. Matrix-forming grasses grow into a carpet that effectively chokes out and eliminates other species. Greater diversity can be correlated with the ability of certain species to tolerate the stress placed upon them through grazing better than others. By decreasing the dominance of big bluestem and other matrix forming grasses, grazing can increase the survival of other species thereby increasing plant diversity (Collins 1987). For example, under heavy grazing big bluestem generally decreases in abundance because it is less tolerant to grazing than the other species (Herbel and Anderson 1959).

This diversity is brought about by the characteristic grazing patterns of large herbivores. Herbivores frequently return to the same areas to graze. Grazers create patches by preferring one area for feeding over another, and they apparently are attracted to the patches they create (McNaughton 1984). These highly selected areas are defoliated to a greater extent compared to less preferred areas. This causes certain areas to be placed under a higher degree of stress due to the intensity of defoliation that they receive.

In unburned prairie, grazed patches are stable and used repeatedly from year to year, resulting in the development of a patchy grazing mosaic (Hobbs et al. 1991). The action of grazing results in both injury to the individual plants and changes in community physiology. The community reacts directly to the grazing event by death or regrowth in response to the injury and indirectly by a regrowth response to the altered physiognomy (Milchunas et al. 1988).

Individual species are affected differently by the stress placed upon them from grazing. If the growing point of a plant is below the height susceptible to removal by grazing, these species would be expected to be the resistant to grazing (Branson 1956). The stress caused by the defoliation manipulation will bring about growth in the form of regrowth and horizontal tillering or spread by rhizomes and stolons. In the highly stressed areas, aboveground and below-ground growth are stimulated and plant diversity is increased due to the ability of certain plants to deal with grazing stress better than others. Thus, the grasses subjected to planned management produce more productive root systems, more foliage, and increased plant diversity.

The fact that we did not find a statistically significant difference between the 30 cm and 40 cm or

Table 4. Grass/forb ratios at different topographic locations.

Treatment	Top	Side	Bottom
Litter removed	1.3/1	1/1	1/2.0
Litter Present	1.9/1	1/1	1/1.5
control	2.5/1	1/1	2/1.0

between the 50 cm and control samples demonstrates that pruning (grazing) is only effective at intense levels. Plant diversity was increased by both the simulated grazed plots and the simulated hayed plots. This can be an advantage for herbivores if the plants are palatable and nutritious. The wild alfalfa is an example of one of the favorable plants. Plants such as ragweed, snow-on-the-mountain, and knotweed offer few positive benefits.

Topographical Location

Topography affects the productivity of grasslands. Annually burned lowland sites had a significantly higher net primary production than either annually burned uplands or unburned uplands or unburned lowlands (Briggs and Knapp 1995). Certain topographic locations will select for a greater diversity of species in grasslands. Species richness was significantly higher on upland soils compared to lowland soils on both annually burned and unburned prairies located at the Konza Prairie Research Natural Area (Abrams and Hubert 1987). Data suggest land-use practices and topographic positions interact to determine the effect climatic variation may have on net primary productions in grasslands.

CONCLUSIONS

To determine the most productive management schemes, the positive and negative effects of each manipulation influencing the prairie ecosystem must be weighed. The haying manipulation greatly increased the growth, but it also favored a smaller grass/forb ratio.

In the past, uncontrolled semi-yearly fires were used to remove this choking litter, stimulate the prairie ecosystem, and decrease the competition of invader species. As fires have become less frequent, haying is becoming an economical means of managing ungrazed natural grasslands.

This introduces problems, in that the prairie ecosystem is not being subjected to the other biologically important properties that fires bring to the mixed grass ecosystem. Some advantages of late-spring burning include incorporation of nutrients, stimulation of growth by increasing soil temperature, elimination of nongrasses with little tolerance to fire, and increasing soil fertility. When haying is the management practice of choice, most litter is removed from the prairie floor therefore removing the nutrients from the system.

From the results of this experiment, a suggestion for management of these mixed grass prairies of Harlan County Reservoir would incorporate yearly haying for a maximum of 3 years, then inspecting the grasslands to determine if the manipulations are enhancing the condition and productivity of the prairie.

One of the easier plant community characteristics is the grass/forb ratio. If the populations of undesirable forbs have increased or are destabilizing the prairie, management practices other than haying may need to be used. Controlled burns often help. A late-spring burn should subject the forbs and nongrasses to enough stress to lower the plant diversity and rejuvenate the soil and prairie ecosystem.

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EFFECTS OF PRAIRIE FIRE AND GRAZING ON BROWN THASHER NEST PREDATION

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Abstract: Both fire and grazing are common land management practices within the tallgrass prairie of northeastern Kansas. Yet, their combined effects on the nesting success of the avian community is poorly understood. I examined the effects of fire and grazing on the nesting success of a brown thrasher (*Toxostoma rufum*) population breeding on the Konza Prairie Research Natural Area. Thrashers breeding on Konza experienced intense nest predation throughout the study. In 1 year, thrashers breeding in burned-grazed prairie experienced significantly lower daily nest survival than birds breeding within other treatments. In addition, thrashers breeding in burned-grazed sites initiated nesting significantly later than birds breeding on ungrazed sites. Because thrashers in this population experience a seasonal decline in the mass of nestlings near the time of nest leaving, a delay in nesting may result in fledglings being produced at a lower mass. This can be important to the reproductive success of parents, since fledgling mass can influence postfledging survival.

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Key words: Kansas, Konza Prairie Research Natural Area, nesting success, tallgrass prairie, *Toxostoma rufum.*

Nest predation is the primary factor reducing the breeding success of many open-nesting birds (Ricklefs 1969, Martin 1992). High predation rates brought about by changes in land management practices and habitat fragmentation have caused fluctuations in bird populations (Angelstam 1986, Sherry and Holmes 1992). Because of population declines, the avifauna of the tallgrass prairie has become a national conservation concern (Askins 1993, Knopf 1994). Therefore, I examined the effects of common land management practices (fire and grazing) on the abundance and productivity of brown thrashers (*Toxostoma rufum*), a core species of the unburned tallgrass prairie (Zimmerman 1993).

Both periodic fire and grazing have historically been prominent features of the natural ecology of the tallgrass prairie. Fire has had an important role in the evolution and maintenance of tallgrass prairie, suppressing woody encroachment were otherwise forest could have been the dominant vegetation type (Anderson 1990). Similarly, grazing by native ungulates such as bison (*Bison bison*) had a great impact on species composition and the structure of vegetation (Collins and Steinauer 1998). In fact, Collins and Benning (1996) considered bison the *keystone species* of the tallgrass prairie.

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Today, the largest remaining tract of undisturbed tallgrass prairie exists in the Flint Hills of Kansas, where both fire and grazing continue to be important ecological processes. Although the role of fire has not changed since presettlement time, both its frequency and extent is now controlled by humans (Anderson 1990). In addition, the role of grazing has also changed as native ungulates have been replaced by domesticated cattle.

Cattle ranching is the most prevalent land use within the Kansas Flint Hills. It is estimated that over 1 million head of cattle graze Flint Hills prairie each summer (Anonymous 1997). Spring burning is an important management tool used by cattle producers, because fire reduces the coverage of woody vegetation and increases primary productivity of grasses (Collins and Gipson 1990). This increase in productivity translates into greater mass gain in cattle. In fact, steers grazed on burned prairie put on 38% more mass during May than steers grazed on unburned pastures (Anderson et al. 1970). Consequently, 50-70% of tallgrass prairie within the Flint Hills is burned and grazed each spring (Anonymous 1997).

The combination of grazing and burning reduces the height and density of the plant canopy, reduces the litter layer, alters plant species composition and increases the proportion of bare soil (Hartnett et al. 1997). These modifications in vegetation structure may have important effects on predator populations and may increase nest predation by increasing the conspicuousness of nests to predators (Zimmerman 1997). Despite the prevalence of periodic fire and grazing within the Flint Hills, their combined effects on avian populations is poorly understood (but see Zimmerman 1997 and Kaufman et al. 1998). Therefore, I monitored a population of brown thrashers breeding on burned-grazed, unburned-grazed, burned-ungrazed, and unburned-ungrazed prairie to assess the effects on relative abundance and reproductive success.

METHODS

Study Area

This study was conducted on the Konza Prairie Research Natural Area located approximately 10 km south of Manhattan, Kansas (39° 05'N, 97° 35'W) from 1993-1996. Konza lies within the Flint Hills physiographic province and is a 3,487-ha ecological preserve owned by the Nature Conservancy and managed by the Division of Biology of Kansas State University. The Flint Hills region is characterized by steep-sided hills exposing alternating limestone-shale layers and is dominated by warm season prairie grasses with scattered shrubs and trees (Reichman 1987). The total area covered by the Flint Hills (50,000 km^2) makes it 1 of the largest tracts of undisturbed tallgrass prairie remaining in North America. The management plan and experimental design of Konza consists of watershed-sized study sites affected by different fire frequencies (from annually to every 20 yr) and grazing treatments (by either cattle or bison or ungrazed).

Species

In northeastern Kansas, brown thrashers are migratory, arriving in early April. According to Zimmerman (1993) and from my own observations, brown thrashers are single brooded and begin nesting from early May until mid-July. Nests are constructed of twigs and grasses (Bent 1948, Partin 1977) and in northeastern Kansas, placed primarily within patches of dogwood (*Cornus drummondii*) and plum (*Prunus sp.*), in small trees (e.g. *Ulmus americana*) or in shrubs such as aromatic sumac (*Rhus aromatica*). Brown thrashers are monogamous with both parents participating in incubation and brooding, but females spend the majority of time on the nest (Erwin 1935, Partin 1977).

General Procedures

The combined effects of burning and grazing were examined by comparing the abundance and productivity of brown thrashers breeding in each of 4 combinations of fire (burned and unburned) and grazing (grazed and ungrazed). Prescribed burning of sites utilized in this study took place in April of each year. Cattle are grazed on Konza, as well as throughout the Flint Hills, from May through October. Grazing intensity on Konza is considered moderate for the region and is established such that cattle remove 20-30% of the annual aboveground plant growth during the season. This stocking rate is equivalent to approximately 3 ha/cow-calf pair. I initiated nest monitoring in 1994 on unburned-grazed and unburned-ungrazed sites. In 1995, a third treatment, burned-grazed, was added to the experiment. The fourth treatment, burned-ungrazed was added in 1996 (Table 1).

The relative abundance of thrashers within each treatment was determined by the variable distance point count method (Ralph et al. 1992) with points spaced ≥ 250 m apart. Data were collected by counting the number of individuals during 10-min intervals within each treatment area. Counts were

Table 1. Study site descriptions (U-U = unburned-ungrazed, U-G = unburned-grazed, B-U = burned-ungrazed, and B-G = burned-grazed.

Year	Treatment	No. Sites	Area of Sites (ha)	Nests Monitored
1994	U-U	3	89.6, 36.1, 35.6	19
	U-G	1	92.5	15
1995	U-U	7	100, 89.6, 75.6, 51.8, 36.1, 35.6, 19.2	44
	U-G	1	92.5	11
	B-G	2	87.5, 82.0	5
1996	U-U	9	89.6, 57.1, 51.8, 27.7, 22.7, 36.1, 35.6, 19.2, 10.0	45
	B-G	3	92.5, 87.5, 82.0	23
	B-U	7	100, 75.6, 62.8, 37.0, 23.6, 16.1, 7.7	31

made from 1993-1995 in mid-May, mid-June, mid-July and mid-August, encompassing the entire breeding period. The average number of individuals per 10-min interval was determined during each census for each site and compared between treatments.

Beginning in 1994, study sites were regularly surveyed for nesting activity and nests were located by systematic searches of potential nest sites, observing the behavior of adults, and by checking old nests from previous years. Because thrashers lay only 1 egg/day, the laying date of first eggs (clutch initiation date) was determined by back dating when nests were found prior to clutch completion. Clutch sizes were assigned for a nesting attempt when the same number of eggs was recorded on 2 consecutive visits and there was evidence that incubation had commenced (i.e. adult behavior and egg temperature). Clutch initiation dates were also estimated for nests located after clutch completion and in which nestlings successfully hatched [hatching date-((clutch size -1) + 12 days incubation)]. Nests were classified as either early or late based on their temporal relation to the median date of clutch initiation each year. The status of extant nests (presence of eggs, nestlings, parents) was determined by visitations every 3-4 days. This frequency of nest visitation is effective in diminishing the impact of human observers on nest predation (Martin and Roper 1988, Major 1990, Martin and Geupel 1993).

Because fire and grazing can influence primary productivity and thus insect abundance (Warren et al. 1987), I measured offspring condition by weighing nestlings to the nearest 0.1 g on Pesola Spring scales (1994-1995) and portable electronic balances (1996) near the time of nest-leaving (brood day 8 or 9).

Nests were defined as successful if at least 1 nestling survived to nest-leaving. A failed nest was classified as depredated if all eggs or nestlings disappeared prior to the expected date of nest-leaving and there was no basis for weather-induced mortality. Parental cues were also used to determine the fate of nests. I have noticed that parents remain aggressive in the vicinity of the nest site once nestlings have successfully fledged but are not aggressive following the loss of nestlings to predation.

Potential nest predators found on Konza are numerous and include at least 8 species of snakes, American crows (*Corvus brachyrhynchos*), opossums (*Didelphis virginiana*), raccoons (*Procyon lotor*), long-tailed weasels (*Mustela frenata*), least weasels (*Mustela nivalis*) and several small rodent species. Previous work on Konza has suggested that snakes are the primary nest predator (Cavitt 1998b) and the only observed incidences of nest predation have been by snakes (Facemire and Fretwell 1980). The appearance of the nest after a predation event was classified according to damage and the state of contents (e.g. all contents missing, egg shell remains in nest lining, etc.), because it is assumed that snake predators leave the nest relatively undisturbed following a predation event whereas larger mammals are more likely to disrupt the nest lining when contents are removed (Thompson and Nolan 1973, Best 1978, Nolan 1978).

Analyses

Most statistical analyses were conducted using PC-SAS (SAS Institute 1996); tests of significance were set at $\alpha = 0.05$. Parametric analyses were used unless transformations were unable to correct for deviations in normality or heterogeneous variances. To avoid pseudo-replication, clutch initiation dates, clutch size, mean number of fledglings produced per nest attempted and mean brood mass were averaged for each site, and then analyses were performed on the average value per site. The effect of burning and grazing treatments on clutch initiation dates, clutch size and mean brood mass were made with ANOVAs ([PROC GLM] *F* value reported). Treatment comparisons of the number of fledglings produced per nest attempted were made by a Kruskal-Wallis nonparametric ANOVA ([PROC NPAR1WAY] X^2 value reported). I examined nesting success by estimating daily survival rates (DSR) and their associated SE according to Mayfield's (1961, 1975) method as modified by Johnson (1979) and Hensler and Nichols (1986). Variation in DSR was compared using the program CONTRAST ([Sauer and Williams 1989] X^2 value reported). The Bonferroni correction for unplanned multiple comparisons was utilized in follow-up tests. Tests of independence (Gadj value reported) with William's corrections for sample size (Sokal and Rohlf 1981) were used to determine if associations existed between pairs of variables.

RESULTS

Fig. 1 shows that the relative abundance of brown thrashers varied significantly with month of census ($F = 10.39$; df = 3,32; $P = 0.0001$) and treatment ($F = 10.27$; df = 3,32; $P = 0.0001$), but there were no significant interactions between month and treatment ($F = 1.20$; df = 9,32; $P = 0.330$). Thrasher relative abundance in all sites was lowest during the August census relative to both the May and June census ($P < 0.003$). Relative abundance was also greatest in the burned-grazed treatment

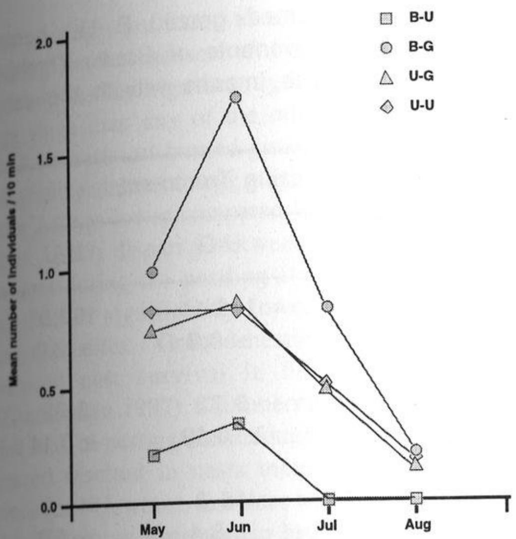

Fig. 1. Mean relative abundance of brown thrashers for each fire and grazing treatment by month of census. Relative abundance on all sites was significantly lower in August relative to either May or June ($P < 0.002$). Relative abundance was significantly greater on burned-grazed sites during each month relative to burned-ungrazed and unburned-grazed sites.

relative to either the burned-ungrazed and unburned-grazed sites ($P < 0.003$). Furthermore, unburned-ungrazed sites had significantly higher abundances relative to burned-ungrazed sites ($P < 0.005$).

A total of 193 brown thrasher nests was located and monitored for this study. There were no significant yearly differences in the Julian date of clutch initiation ($F = 1.47$; df = 2,21; $P = 0.965$), clutch size ($F = 0.53$; df = 2,25; $P = 0.594$), the number of nestlings fledged per nest attempted ($X^2 = 1.531$, df = 2, $P = 0.465$), or mean broodmass ($F = 1.20$; df = 2,16; $P = 0.328$), so years were pooled in analyses of these variables. Thrashers initiated clutches significantly later on burned-grazed sites than either of the 2 unburned treatments. Treatment had no detectable effect on clutch size or the mean number of fledglings produced per attempted nest. In addition, mean broodmass was not significantly affected by burning or grazing treatments (Table 2).

Predation was the most important source of mortality throughout this study and accounted for a total of 146 nest losses. There was no significant differences between treatments in the condition of nests (disturbed versus undisturbed) following predation events (% undisturbed-burned-grazed = 1.0, unburned-grazed = 0.82, burned-ungrazed = 1.0, and unburned-ungrazed = 0.905; Gadj = 3.815, df = 3, $P > 0.05$). The DSR of nests during the laying (n = 72) and incubation (n = 150) periods did not differ significantly ($X^2 = 1.8$, df = 1, $P = 0.179$), therefore these periods were pooled and considered together as the egg stage. The DSR during the nestling period (n = 66) was significantly higher than either the laying or incubation stage ($X^2 = 14.44$, df = 1, $P = 0.0001$).

Considerable yearly variation in DSR existed for this population during the egg stage, so each year was analyzed separately. As shown in Fig. 2, there was no significant difference in egg stage DSR between treatments or seasons during 1994 ($X^2 = 5.039$, df = 3, $P = 0.169$. However, both season ($X^2 = 7.52$, df = 1, $P = 0.006$) and treatment ($X^2 = 7.926$, df = 1, $P = 0.005$) significantly affected egg stage DSR in 1995. During the early season of 1995, unburned-ungrazed sites had significantly lower egg stage DSR than unburned-grazed sites ($X^2 = 73.788$, 1 df, $P = 0.00001$). The egg stage DSR of nests on unburned-grazed sites declined throughout the remainder of 1995 such that no difference existed during the late season ($X^2 = 2.119$, 1 df, $P = 0.145$). During the 1996 breeding season, nests initiated during the early

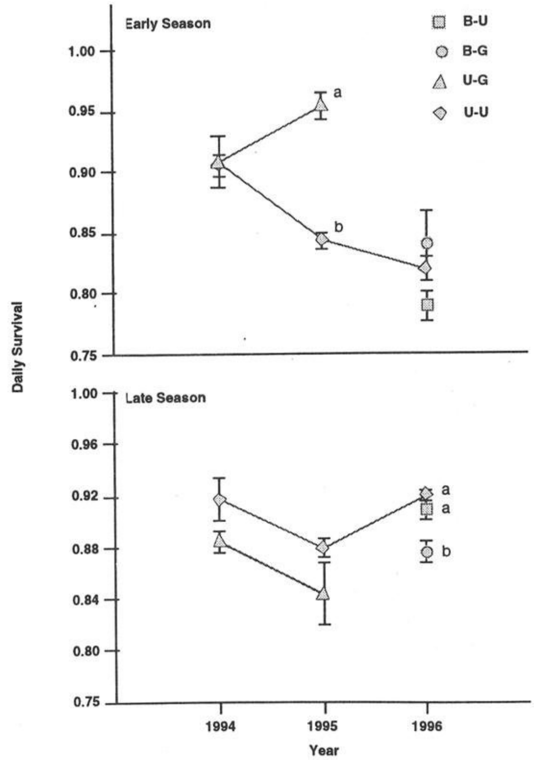

Fig. 2. The effects of fire and grazing treatment on the egg stage daily survival rate of bown thasher nests (means with the same letter ar not significantly different $P < 0.05$).

Table 2. Means (± SE) showing the effects of fire and grazing (B-G = burned- grazed, B -U = burned ungrazed, U-G = unburned-grazed, U-U = unburned-ungrazed) on components of Brown Thrasher reproductive success (analyses performed on the average value per site, means witwith the same letter are not significantly different, P = 0.05).

Component of Reproductive Success	Statistic	Fire and Grazing Treatment			
		B-G	B-U	U-G	U-U
Julian date of Clutch Initiation	F = 3.04; df = 3,25 P = 0.047	175.0[a] ± 5.3	161.8[a,b] ± 5.3	153.1[b] ± 8.3	157.9[b] ± 2.9
Clutch Size	F = 0.62; df = 3,24 P = 0.611	3.43 ± 0.25	3.29 ± 0.25	3.73 ± 0.39	3.22 ± 0.14
Mean Broodmass (g)	F = 0.83; df = 3,211 P = 0.49	42.5 ± 2.1	40.7 ± 2.4	46.3 ± 3.4	41.0 ± 1.3
No. Fledge/ Nest Attempted[1]	X^2 = 0.656, df = 3 P = 0.883	1.43 ± 0.37	1.20 ± 0.37	0.36 ± 0.64	0.59 ± 0.21

[1]For ease of comparison, means and SE are reported for analysis.

season had significantly lower egg stage DSR relative to late season nests (X^2 = 51.28, 1 df, P = 0.00001). Burning and grazing treatments did not differ significantly during the early season (X^2 = 4.92, 2 df, P = 0.086), but the egg stage DSR was significantly affected by treatment during the late season (X^2 = 24.22, 2 df, P = 0.00001). Nests in burned-grazed sites had significantly lower egg stage DSR relative to either unburned-ungrazed sites (X^2 = 24.2, 1 df, P = 0.00001) or burned-ungrazed sites (X^2 = 9.03, 1 df, P = 0.003). In fact, late season Mayfield estimates of nest success reveal that the probability of producing a successful nest through the incubation period is considerably lower on burned-grazed sites relative to the other treatments (burned-grazed = 0.13, burned-ungrazed = 0.24, unburned-ungrazed = 0.28).

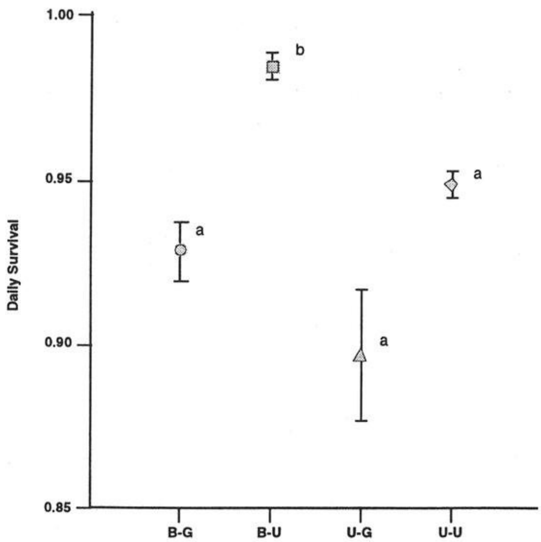

Fig. 3. The effects of fire and grazing treatment on the nestling stage daily survival rate of bown thasher nests (means with the same letter ar not significantly different $P < 0.05$).

As shown in Fig. 3, the DSR during the nestling stage did not differ significantly between years (X^2 = 2.364, 2 df, P = 0.307) or season (X^2 = 1.543, df = 1, P = 0.214), but differed between treatments (X^2 = 18.79, df = 3, P = 0.0003). The nestling stage DSR in burned-ungrazed sites was significantly greater than any other treatment. Nestling stage DSR was also significantly lower on all grazed sites relative to ungrazed treatments (pooled grazed treatments = 0.913, pooled ungrazed treatments = 0.967, X^2 = 23.28, df = 1, P = 0.0001).

DISCUSSION

The results of this study demonstrate considerable temporal variation, both seasonally and yearly, in the daily survival of brown thrasher nests. This is not surprising considering the extreme temporal variation in snake populations also found on this site (Cavitt 1998a, 1998b). The combined effects of burning and grazing were found to affect the DSR of nests. During the late season of 1996, nests on burned-grazed sites had significantly lower DSR during the egg stage than any of the other treatments. Low DSR of nests on burned-grazed prairie resulted in Mayfield estimates of egg stage nesting success more than 2 times lower compared to unburned-ungrazed sites. Such disparity between treatments was not evident during the nestling stage, but grazing also resulted in significantly lower DSR compared to ungrazed sites. Ground-nesting species also have reduced nest survival in burned-grazed prairie (Zimmerman 1997). Zimmerman (1997) suggested that lack of nesting cover found on sites burned and grazed resulted in nests more vulnerable to nest predation. However, this does not adequately explain the differences observed in brown thrasher nesting success since thrashers nest within the shrub layer which is not as severely impacted by fire or grazing. Rather, these results may be due to a difference in predator abundance and diversity on sites burned and grazed.

I have captured a greater frequency of snakes early in the season on unburned prairie but this pattern changes such that the frequency of captures is greater on burned sites during the late season. This suggests that snakes may move into burned sites later in the year as the height of the vegetation increases.

The combination of burning and grazing also significantly delays the onset of thrasher clutch initiation by more than 2 weeks relative to unburned-ungrazed sites. A similar delay in nesting on burned-grazed prairie was found in a population of dickcissels (*Spiza americana*) nesting on Konza (Zimmerman 1997). Zimmerman (1965, 1997) suggested that this delay may be detrimental to the survival of female and young Dickcissels by adversely affecting their ability to acquire sufficient energy to meet the demands of molt and fall migration because of seasonal limits imposed by photoperiod and temperature. It is unclear if thrashers would experience similar increases in mortality with delays in nesting. However, a delay in nesting may be costly in terms of reproductive success. It has been demonstrated in this population that the mass of nestling thrashers near the time of nest leaving declines significantly during the breeding season (Cavitt 1998b). Thus, a delay in nestling production may result in nestlings fledging at a lower mass. Studies on other species have found that mass at nest leaving is positively correlated with post-fledgling survival (Perrins 1965, Moss 1972). Because this population has been classified as a "breeding sink" (Cavitt 1998b), further experiments on the effects of fire and grazing need to be conducted on other populations of thrashers.

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RARE SPECIES OF SMALL MAMMALS IN NORTHEASTERN KANSAS TALLGRASS PRAIRIE

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Abstract: We sampled small mammals in native tallgrass prairie habitat from autumn 1981 to spring 1998 on Konza Prairie Research Natural Area, Kansas. In 130,560 trap-nights, we captured 14 species of small mammals. In decreasing order of abundance, the relatively common species were the deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomys megalotis*), Elliot's short-tailed shrew (*Blarina hylophaga*), white-footed mouse (*P. leucopus*), prairie vole (*Microtus ochrogaster*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), and hispid cotton rat (*Sigmodon hispidus*). Likewise, rare species were the southern bog lemming (*Synaptomys cooperi*), hispid pocket mouse (*Chaetodipus hispidus*), eastern woodrat (*Neotoma floridana*), house mouse (*Mus musculus*), plains harvest mouse (*Reithrodontomys montanus*), least shrew (*Cryptotis parva*), and meadow jumping mouse (*Zapus hudsonius*). Relative abundances of the rare species ranged from 0.002 (individuals/trapline/sampling period) for the meadow jumping mouse to 0.112 for the southern bog lemming. All rare species combined comprised approximately 2% of the small mammal community in grasslands on Konza Prairie. Southern bog lemmings selectively used sites that were left unburned for 2-3 years in contrast to those burned annually and those unburned for ≤ 4 years. Time since fire had no detectable effect on numbers of individuals for the other 6 rare species. In addition, southern bog lemmings, eastern woodrats, and hispid pocket mice were distributed nonrandomly with respect to topography.

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Key words: *Chaetodipus hispidus*, *Cryptotis parva*, eastern woodrat, fire, hispid pocket mouse, house mouse, Konza Prairie Research Natural Area, least shrew, meadow jumping mouse, *Mus musculus, Neotoma floridana*, plains harvest mouse, *Reithrodontomys montanus*, southern bog lemming, *Synaptomys cooperi*, topography, *Zapus hudsonius*.

Long-term studies are essential to examine ecological processes that have high annual variability (Franklin 1989). Population and community dynamics of small mammals typically have high inter- and intra-annual variability, especially in temperate regions (e.g. Sexton et al. 1982, Krohne and Burgin 1990). However, most studies of small mammals are short in duration (≤ 3 yrs). Data from short-term studies may be misleading due to slow processes, rare or episodic events (e.g., incidence of disease, wildfire occurrence, and extremes in precipitation, temperature, and production of seeds), or processes with high variability (Franklin 1989, Tilman 1989). In 1981, we initiated a long-term study to assess temporal variability in abundance of small mammals in native tallgrass prairie on the Konza Prairie Research Natural Area in northeastern Kansas. During 17 years of sampling, we captured 14 species of small mammals (Finck et al. 1986, McMillan et al. 1997).

For the purposes of this paper, we consider half of the species (7) to be rare on the site. Herein, we provide information gathered to date, on abundance and habitat selection in native tallgrass prairie for these rare species.

METHODS

Study Site

We studied small mammals in native tallgrass prairie on Konza Prairie Research Natural Area. Konza Prairie is a 3,500-ha field research station, which is composed of flat uplands with shallow soils, terraced by layers of Permian limestone, and lowlands with relatively deep soils. These conditions are typical of the Flint Hills region. Maximum topographic relief is approximately 130 m. Tallgrass species that dominate the site include big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparius*), and switchgrass (*Panicum virgatum*). Common forbs include heath aster (*Aster ericoides*), western ragweed (*Ambrosia psilostachya*), and fringeleaf ruellia (*Ruellia humilis*). In addition to bur oak (*Quercus macrocarpa*), chinquapin oak (*Q. muhlenbergii*), hackberry (*Celtis occidentalis*), American elm (*Ulmus americanus*), and honey locust (*Gleditsia triacanthos*) in the extreme lowlands, scattered patches of smooth sumac (*Rhus glabra*) and rough-leaved dogwood (*Cornus drummondii*) occur across the site.

Our specific study area encompassed approximately 4 km^2 and included 28 sites from an array of native grazer and fire treatments. Native grazer treatments included 6 sites grazed by bison (*Bison bison*) since 1991. Fire treatments included burning once every year (6 sites), every 2 years (4 sites), every 4 years (10 sites), every 10 years (2 sites), and every 20 years (6 sites). All prescribed burning was conducted during early spring (typically April).

Small Mammal Sampling

We sampled small mammals from autumn 1981 to spring 1998. Although all sites were not sampled during each year, at least 20 sites and up to 28 sites were trapped in each sampling period during 1981-1987 and at least 14 sites and up to 18 sites were trapped each sampling period during 1988-1998. Trapping was conducted during each spring (typically March), summer (typically July), and autumn (typically October) from autumn 1981 to autumn 1987, whereas trapping was conducting only during spring and autumn from spring 1988 to spring 1998.

We established a permanent trapline of 20 stations at each site. Sampling periods consisted of setting 2 large Sherman live-traps (7.6 x 8.9 x 22.9 cm) at each station for 4 consecutive nights. Traps were baited with a mixture of peanut butter and rolled oats (Kaufman et al. 1988). During the summer sampling periods, traps were closed during the day to decrease trap-related mortality. All small mammals were marked to identify individuals at their first capture. At each capture, basic live-trap data including species, sex, and trap station were recorded. Our total study involved 130,560 trap-nights of effort.

Analyses

We used log-likelihood ratios (G -test) to test for intraspecific differences in numbers of individuals related to fire treatments and topographic habitat. We used the relative proportion of stations available each year related to time since fire and topography to calculate our expected values for the G -test. For fire treatment, categories were 1 year (burned), 2-3 years (intermediate unburned), and ≥ 4 years (long-term unburned) since fire. We used the topographic categories of upland, breaks, and lowland for analyses of habitat selectivity. For individuals that were captured more than once in a sampling period, we used data only from the initial capture in our statistical analyses. We made no attempt to assess differences associated with grazing treatments because too few individuals were captured.

RESULTS

The 7 most common mammal species in decreasing order of abundance (Fig. 1) were the deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomys megalotis*), Elliot's short-tailed shrew (*Blarina hylophaga*), white-footed mouse (*P. leucopus*), prairie vole (*Microtus ochrogaster*), thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*), and hispid cotton rat (*Sigmodon hispidus*). These were considered "common" small mammals.

The 7 least abundant mammal species (considered "rare" small mammals) were the southern bog lemming (*Synaptomys cooperi*), hispid pocket mouse (*Chaetodipus hispidus*), eastern woodrat (*Neotoma floridana*), house mouse (*Mus musculus*), plains harvest mouse (*Reithrodontomys montanus*), least shrew (*Cryptotis parva*), and meadow jumping mouse (*Zapus hudsonius*). Relative abundances of these species ranged from 0.002 (individuals/trapline/sampling period) for the meadow jumping mouse up to 0.112 for the southern bog lemming. All 7 species combined comprised 2.1% of the community of small mammals from 1981 to 1998 (Table 1).

Mean number (± SE) of the 7 rare species captured during each sampling period (N = 40) was 1.85 ± 0.22. More specifically, mean number of rare species captured was 1.12 ± 0.17, 2.17 ± 0.48, and 2.47 ± 0.40 for spring (N = 17), summer (N = 6), and autumn (N = 17) sampling periods, respectively. Number of the 40 sampling periods each species was captured ranged from 2 for the meadow jumping mouse to 20 for the southern bog lemming (Table 1). Only 2 meadow jumping mice were captured during the entire study, and therefore are not included in further analyses.

Although rare, southern bog lemmings, hispid pocket mice, eastern woodrats, house mice, plains harvest mice, and least shrews all were caught on each day of our 4-day sampling period. Further, 4 or possibly 5 of the 6 species exhibited a reduction in the number of new individuals captured toward the end

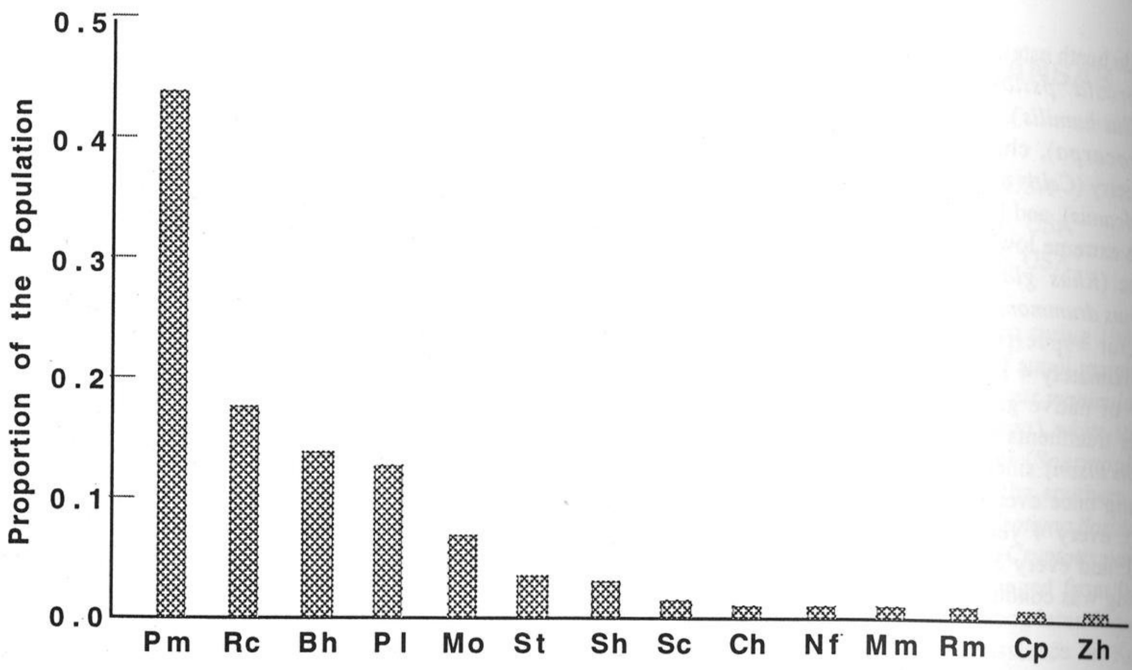

Fig. 1. The proportion of the small mammal community made up of each of the fourteen species captured in native tallgrass prairie. The species captured were Peromyscus maniculatus (Pm), Reithrodontomys megalotis (Re), Blarina hylophaga (Bh), P. leucopus (Pl), Microtus ochrogaster (Mo), Spermophilus tridecemlineatus (St), Sigmodon hispidus (Sh), Synaptomys cooperi (Sc), Chaetodipus hispidus (Ch), Neotoma floridana (Nf), Mus musculus (Mm), R. montanus (Rm), Cryptotis parva (Cp), and Zapus hudsonius (Zh). Sampling was conducted on Konza Prairie Research Natural Area during autumn 1981-spring 1998.

of our sampling periods (Fig. 2). Only the eastern woodrat did not show a decreasing rate of capture by day 4.

Both fire treatment and topography significantly influenced habitat selection by the rare species. Southern bog lemmings selectively used sites that were 2-3 years since fire and underused annually burned areas ($G = 22.0$, d.f. = 2, $P < 0.001$).

However, number of years since the last fire had no detectable effect on number of individuals captured for the other rare species. Two species, the eastern woodrat and hispid pocket mouse, selectively used breaks habitat ($G = 4.24$, d.f. = 2, $P < 0.1$ and $G = 38.35$, d.f. = 2, $P < 0.001$, respectively) over uplands and lowlands, whereas the southern bog lemming preferred lowland habitat ($G = 5.31$,

Table 1. The percent of the small mammal community, number of individuals captured, and mean number per trapline (relative abundance) for each of the seven rare species of small mammals. Also given, are the number of sampling periods (SPs) out of 17 springs, 6 summers, and 17 autumns that each species was captured (# of springs, # of summers, # of autumns). Sampling was conducted in native tallgrass prairie habitat on Konza Prairie Research Natural Area during 1981-1998.

Species	Percent	Number	Number/trapline	SPs
southern bog lemming	1.09	91	0.112	9,3,8
hispid pocket mouse	0.29	24	0.029	3,4,8
eastern woodrat	0.24	20	0.025	3,3,6
house mouse	0.20	17	0.021	0,2,8
plains harvest mouse	0.19	16	0.020	3,0,5
least shrew	0.12	10	0.012	1,0,6
meadow jumping mouse	0.02	2	0.002	0,1,1

meadow jumping mouse 0.02 2 0.002 0,1,1

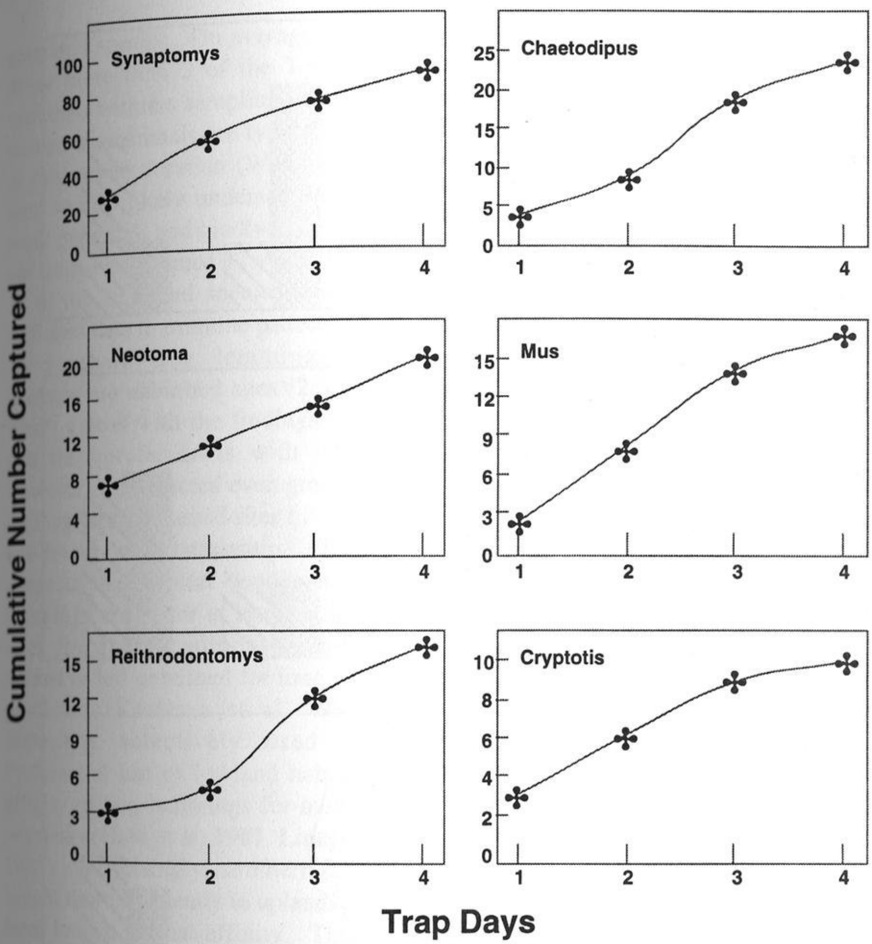

Fig. 2. Cumulative number of new individuals captured during each day 1 of the four-day sampling periods for each of the rare species (except *Z. hudsonius*) of small mammals captured in native tallgrass prairie. Sampling was conducted on Konza Prairie Research Natural Area during autumn 1981-spring 1998.

d.f. = 2, $P < 0.1$) over the other habitat types. Too few individuals were captured to perform statistical analyses for the remaining 4 species. However, greater than expected captures of the house mouse in lowland and breaks, plains harvest mouse in breaks, and least shrew in uplands suggest patterns of differential habitat use if these trends continue with additional captures (Fig. 3).

DISCUSSION

During our 17-year study, we captured all species of terrestrial small mammals thought to occur in prairie habitats on Konza Prairie (Finck et al. 1986, McMillan et al. 1997). Seven of the 14 species of small mammals captured in native tallgrass prairie on Konza Prairie we defined as rare (≤ 0.1 individuals/trapline). Of the 7 species, we expected the eastern woodrat, house mouse, hispid pocket mouse, and meadow jumping mouse to be uncommon or rare in our grassland habitats. The eastern woodrat typically is associated with woody vegetation (Wiley 1980, Bee et al. 1981, Jones et al. 1985, McMillan and Kaufman 1994). Consistent with this habitat association, eastern woodrats occur throughout woody habitats on Konza Prairie (Finck et al. 1986, McMillan and Kaufman 1994, McMillan et al. 1997). Likewise, house mice generally have a commensal relationship with humans, and rarely use native grasslands (Jones et al. 1985, Kaufman and Kaufman, 1990). For the other 2 species, Konza Prairie is located at the edge of their ranges: eastern edge for the hispid pocket mouse and western edge for the meadow jumping mouse (Jones et al. 1985). Therefore, Konza Prairie may represent marginal habitat for these 2 species. In contrast, the southern bog lemming, plains harvest mouse, and least shrew are grassland species and were surprisingly rare on Konza Prairie.

It is possible that these rare species are actually common on the site, but our methods did not accurately or effectively sample the "rare" species. Three possibilities exist: (1) we did not sample the appropriate habitats, (2) Sherman live-traps do not effectively sample all species, and (3) these species do not enter the traps in the first few days of a trapping session.

In the first case, our study sites spanned 4 km^2, and at each site we sampled a transect across habitats representative of the site. However, it is possible that some localized populations associated with specific habitat types were not sampled. For example, least shrews were relatively common on a study area during 1 year of a multi-year investigation conducted during 1983-1987 on Konza Prairie (Clark et al. 1995).

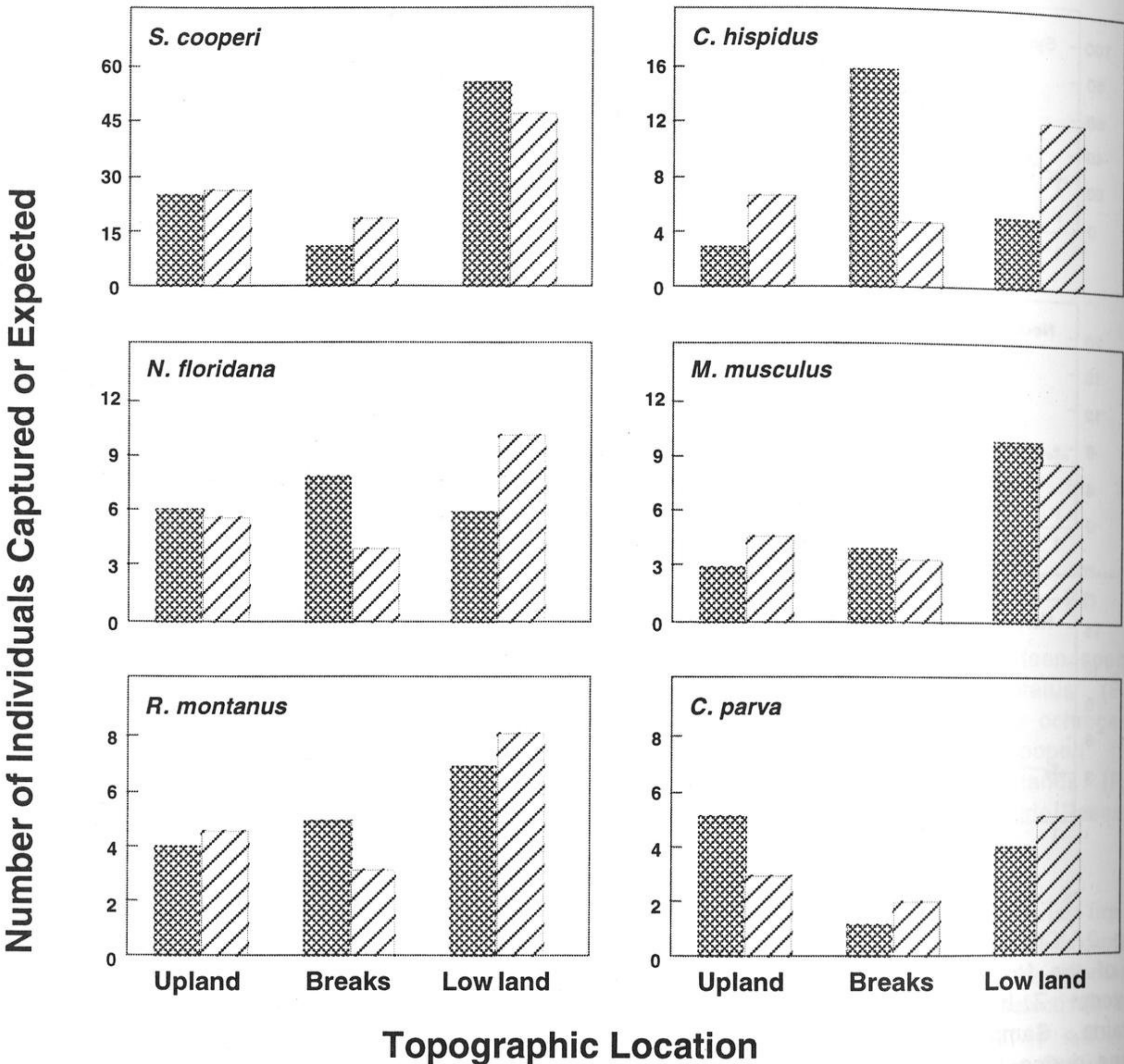

Fig. 3. Number of individuals captured in upland, breaks, and lowland habitats for each of the rare species (except Z. hudsonius) of small mammals captured in native tallgrass prairie. Hatched bars are observed individuals and lined bars are expected number of individuals calculated from the availability of each habitat type. Sampling was conducted on Konza Prairie Research Natural Area during autumn 1981-spring 1998. S. cooperi, C. hispidus, and N. floridana exhibited significantly nonrandom use of available habitats at the $P < 0.001$, $P < 0.1$, and $P < 0.1$ levels, respectively.

Secondly, it is likely that all small mammals on the site are differentially susceptible to capture by Sherman live-traps. However, Sherman live-traps have been used to effectively sample each of the species we consider rare (Clark et al. 1995, Kaufman and Kaufman 1990, McMillan and Kaufman 1994, Zwank et al. 1997), except possibly least shrews, and likely did so in this study.

To determine whether we were effectively sampling the rare species with our trapping methodology, we examined the day of capture for individuals of each species. If our sampling was effective, we would expect captures on the first day of sampling and a decreased number of new individuals toward the end of our 4-day sampling periods. We observed this pattern for 4 and possibly 5 of the grassland species. On average, we captured < 2 and never more than 5 of the 7 rare species of small mammals within a sampling period. Most ecological studies of mammals are typically only 1 to a few (3 or 4) years in duration (Weatherhead 1986). Short-term studies likely undersample species richness of small mammals and biodiversity in general. Because our study has spanned 17 years, we have captured all 14 of the expected species and have accumulated sufficient data to examine patterns for the rare species.

Southern bog lemmings selectively used intermediate unburned sites (2-3 years without fire), which agrees with the findings of Bee et al. (1981) that they prefer areas with a dense litter layer. However, we expected even greater selectivity of use for long-term unburned sites (≥ 4 years without fire), but found no relationship. This pattern of use suggests that habitat conditions for southern bog lemmings are better at intermediate lengths of time after fire than conditions found in sites recently burned or left unburned for long periods of time. As predicted (Kaufman et al. 1995), southern bog lemmings selectively used lowland habitat. Preferential use of lowland habitat agreed with the affinity of bog lemmings for mesic areas with thick vegetation (Bee et al. 1981, Linzey 1983, Jones et al. 1985). Surprisingly, southern bog lemmings were caught more frequently in uplands than seemed likely from known habitat affinity. This pattern suggests that bog lemmings are not as dependent on wet areas as previously thought (Jones et al. 1985), but this needs further investigation.

The eastern woodrat was associated positively with breaks habitat, but not lowland prairie. This finding was somewhat unexpected. However, shrubs and large rocks, which are important habitat features for woodrats (Wiley 1980, Bee et al. 1981, Jones et al. 1985, McMillan and Kaufman 1994), are both associated with limestone outcrops in breaks habitat on Konza Prairie. The distance between wooded ravines and most traplines probably made it unlikely that woodrats would be caught in lowland regions of our prairie lines. However, some of the trap-lines were relatively close to woody ravines, and therefore these data also suggest that woodrats rarely venture into the prairie from areas with woody vegetation.

The hispid pocket mouse selectively used breaks habitat over upland and lowland habitats, which is consistant with an earlier study (Kaufman et al. 1995). This pattern of use was consistent with the association of pocket mice with open, arid grassland areas in rocky, loamy or sandy soils (Kaufman and Fleharty 1974, Bee et al. 1981, Jones et al. 1985, McMillan and Kaufman 1994). Interestingly, pocket mice on Konza Prairie were captured repeatedly at the same station within the same site, although captures of different individuals were separated by multiple years (e.g. 7 of the 24 pocket mice were captured at 3 stations on the same site during 1981, 1983, 1984, 1985, 1990, and 1995). This observation suggests that few locations may be suitable for use by these granivorous mice on the eastern edge of their range (Jones et al. 1985). The rarity of these mice on our traplines was consistent with their preference for annual grasses associated with old-field habitat over native tallgrass prairie at a local site on Konza Prairie (McMillan and Kaufman 1994).

Although we captured too few individuals of the other rare species to perform statistical analyses, the preliminary patterns we found suggest predictions that can be tested with additional captures of these species. House mice appeared to choose lowland and breaks habitat over upland. Use of lowland and breaks over upland habitat by house mice is a pattern that is consistent with a use of farmsteads and agricultural fields and occasional dispersal to native habitats (Bee et al. 1981, Kaufman and Kaufman 1990).

Plains harvest mice appeared to choose breaks habitat over lowland or upland. Selective use of breaks habitat by plains harvest mice agrees with a preference for rocky and dry areas with sparse vegetation (Kaufman and Fleharty 1974, Bee et al. 1981), but is not consistent with preferential use of prairie uplands (Bee et al. 1981).

Least shrews appeared to choose upland over lowland or breaks. Use of more xeric upland habitat by least shrews agrees with earlier reports for this species (Jones et al. 1985, Clark et al. 1995).

We considered about 50% of the native grassland small mammal species to be rare in tallgrass prairie habitats on Konza Prairie. Because they are rare, ecological processes associated with these species are difficult to examine. Because this investigation has been going on for 17 years, we are able to begin to look at ecological characteristics of these rare species. For our investigation into small mammal population and community dynamics in tallgrass prairie (and likely most small mammal studies), a short-term approach would have led to inaccurate or at least incomplete conclusions for these relatively uncommon species.

ACKNOWLEDGMENTS

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SMALL MAMMAL POPULATIONS IN A PRAIRIE/RIPARIAN FOREST ECOTONE

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Abstract: The Platte River valley and the islands in it have become a riparian forest composed primarily of cottonwoods (*Populus deltoides*) and the eastern redcedar (*Juniperus virginiana*). These lands are rarely cultivated or used to any extent for agriculture. Therefore many nonegame wildlife species thrive in these areas without much disturbance by man. Determining small mammal population sizes in this area was our main objective. Live-traps were placed in 3 different habitats (open prairie, scattered redcedar and dense redcedar) on an island of the Platte River in south central Nebraska. In the habitat we labeled **open prairie**, Kentucky bluegrass (*Poa pratensis*) dominated with big bluestem (*Andropogon gerardii*) in second place. A total of 73 small mammals was captured in the open prairies: primarily western harvest mice (*Reithrodontomys megalotis*) and deer mice (*Peromyscus maniculatus*). The **scattered redcedar** usually surrounded the open prairie patches. A total of 95 small mammals was captured in scattered redcedar: primarily deer mice followed by white-footed mice (*P. leucopus*). The **dense redcedar** habitat consisted of a Kentucky bluegrass understory with eastern redcedar leaves covering the floor. A total of 91 small mammals was captured, consisting entirely of deer mice and white-footed mice. The total of 259 captures represented 8 species of small mammals. The removal of the eastern redcedar would reduce the population of deer mice and white-footed mice significantly.

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Key words: deer mouse, eastern redcedar, *Juniperus virginiana*, *Peromyscus leucopus*, *Peromyscus maniculatus*, Platte River, *Reithrodontomys megalotis*, Sherman live-traps, western harvest mouse, white-footed mouse.

Eastern redcedar (*Juniperus virginiana*) is not really a cedar but a member of the cypress family (Cupressaceae) and so named because of the distinctive cedar scent (Hugo 1990). It is used to make "cedar" chests, pencils and other useful items in our everyday life. Harvesting these trees can be an essential tool in managing their numbers. It is very tolerant to drought and can grow in virtually any soil condition. It is heavily resistant to herbicides and harmful insects (Buehring et al. 1971), and has been proven to be very tenacious.

When these trees are destroyed for management purposes, what happens to the wildlife that use them for shelter and food? Holthiujzen and Sharik (1984) found that 71 species use the redcedar seeds as food, 63 of which were birds. Other wildlife species use redcedars as shelter: for example deer (*Odocoileus* spp.), wild turkey (*Meleagris gallopavo*) and several species of small mammals. Which species and in what numbers will often depend on the plants growing beneath the redcedars. What they are will vary with soil condition, water and nutrient availability, and light intensity from the canopy cover of the trees.

The objective of this study was to determine relative numbers of small mammal species present, plant densities of open prairie and understory plants of the eastern redcedar, and plant species diversity within 3 different habitats (dense redcedar, scattered redcedar and open prairie) near the Platte River.

Although an ecosystem is always dynamic, removal of redcedars for habitat management will result in change in the small mammal community. We suspect that the removal of the redcedars will result in a decline of some small mammal populations, particularly those that use the trees for shelter and food. We further suspect that wholesale redcedar removal will affect small mammal populations that live on the forest edge and in the prairie.

MATERIALS AND METHODS

The areas studied were on the Speidell Property (managed by The Nature Conservancy) on Kilgore Island in the Platte River, 5 miles east of Kearney, Buffalo County, Nebraska (Fig. 1). The Global Positioning System was used to determine exact locations of the 3 areas that contained 3 habitats each:

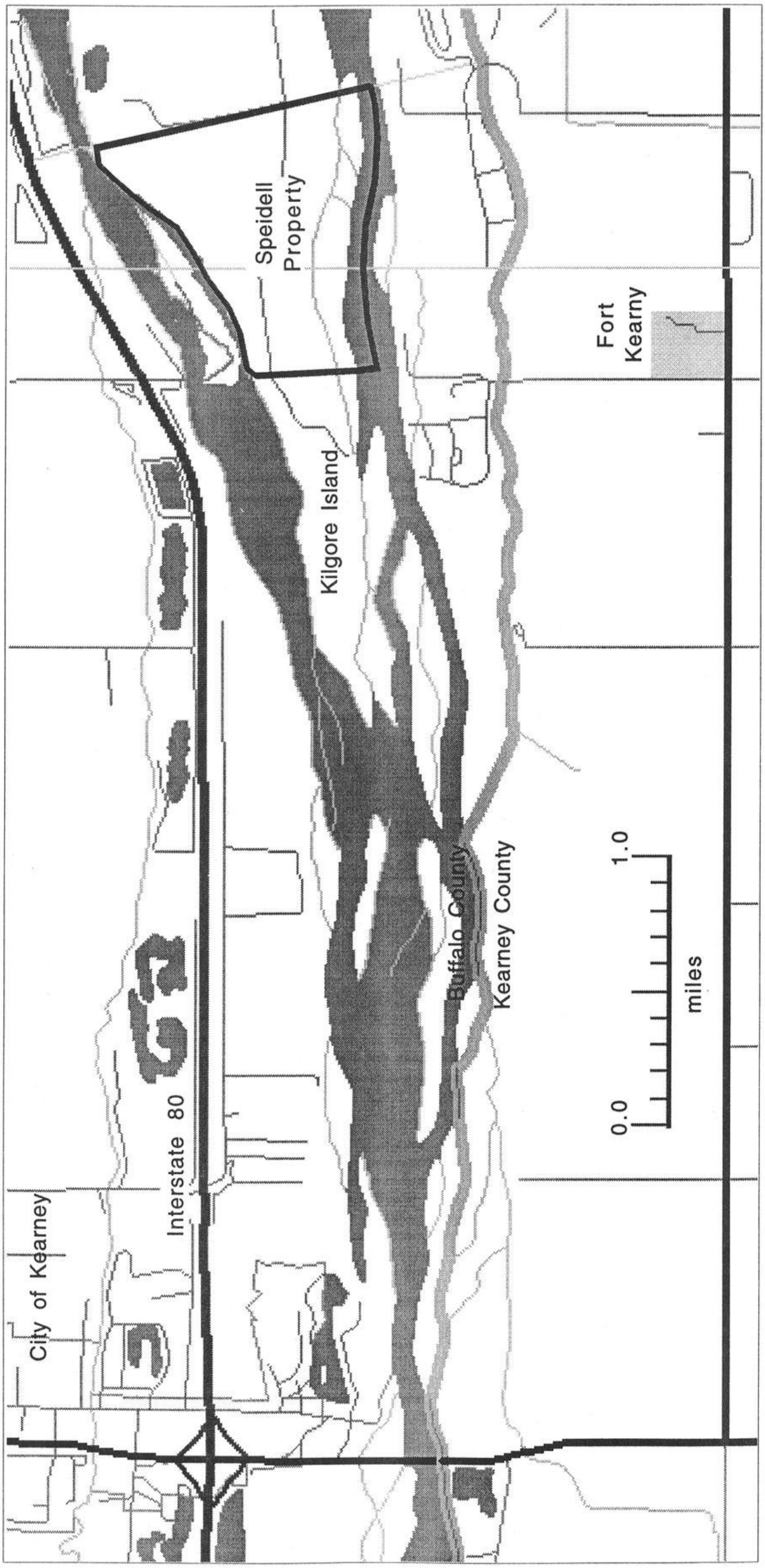

Fig 1. Map showing location of the Speidell Property on Kilgore Island in Buffalo County, Nebraska. This was the area on which small mammals were trapped in fall 1997 on 3 habitat: open prairie, scattered redcedars, and dense redcedars.

dense redcedar, scattered redcedar and open prairie. The first area was located at N 40°, 39', 57.7" and W 99°, 00', 42.8". The second area was located at N 40°, 39', 47.3" and W 99°, 00', 11.2". The third area was located at N 40°, 40', 19.9" and W 98°, 59', 24.8".

This part of Nebraska has an annual precipitation of 63.35 cm, most of which occurs during April through October, and an average temperature of 9.7°C (Nagel et al. 1980).

The sites with **open prairie** had Kentucky bluegrass (*Poa pratensis*) and big bluestem (*Andropogon gerardii*) predominating. The 3 open prairie sites had not been grazed or cultivated for more than 15 years and the litter accumulation is up to 15 cm in some of the areas.

The **scattered redcedar** sites had predominantly Kentucky bluegrass with occasional eastern redcedar.

The **dense redcedar** sites consisted primarily of eastern redcedar with a few cottonwood trees (*Populus deltoides*) interspersed. Kentucky bluegrass was virtually the only species making up the understory.

Sixty-six Sherman live-traps were

Table 1. Numbers of captures for each species found on the three habitats in fall 1997. Blbr = short-tailed shrew, Mipe = meadow vole, Mumu = house mouse, Pele = white-footed mouse, Pema = deer mouse, Reme = western harvest mouse. Numbers in a column followed by different letters are significantly different ($P < 0.05$). Numbers in a column followed by the same letter are not significantly different ($P > 0.05$).

		Species							
Site	Area (m²)	Blbr	Mipe	Mumu	Pele	Pema	Reme	Soci	Total
Open Prairie	400	4[a]	0	0	17[c]	7[f]	44[h]	1	73[j]
Scattered Redcedar	617	0[b]	1	2	42[d]	49[g]	0[i]	1	95[j]
Dense Redcedar	400	0[b]	0	0	46[e]	45[g]	0[i]	0	91[k]
Total	1417	4	1	2	105	101	44	2	259

placed in each area: 22 traps per habitat. The total areas covered by the trap lines varied as indicated in Table 1.

The traps were baited with peanut butter twisted in wax paper (each resembling a Hershey's Kiss®).

Table 2: Average plant density (/m²) of the "Open Prairie" sites.

Species	Density
Kentucky bluegrass	1360
big bluestem	128
switchgrass	49
western ragweed	8
brome grasses	< 1
four o'clock	< 1
slender aster	< 1
common milkweed	< 1
musk thistle	< 1

Table 3: Average understory plant density at "Dense Redcedar" sites. Clearly the understory is dominated by Kentucky bluegrass, but not many plants of any kind grow there.

Species	Density
Kentucky bluegrass	68
Mustard spp.	1
Lichen	< 1
Redcedar sapling	< 1
Smooth brome	< 1

Cottonballs were placed in the traps as nesting material to prevent hypothermia. There was a total of 792 trap-nights from 18 September through 31 October 1997.

Captured small mammals were identified, weighed, measured and marked with a permanent ink marker on the inside skin of both ears for recapture identification.

We used X^2 analysis to determine whether the population density of 1 habitat was significantly different from the other 2 habitats. Species distributions by habitat were also tested using the X^2 analysis.

Plants were collected from 4 sites: 2 samples were taken from each 10-m² quadrat in 1-m² subplots. Four plant samples were taken from the open prairie, and 4 samples were taken from dense redcedar areas. The plants were identified and density levels were established. Light intensity was measured at each 10–m² quadrat.

RESULTS AND DISCUSSION

Table 1 shows how many of each species were captured within the 3 habitats. Fig. 2 shows the average capture frequencies of all habitats.

Plant Density

The dominant plant species was Kentucky bluegrass in the open prairie locations and the dense redcedar understory (Table 2 and Table 3).

Light intensity averaged 7625 ft-candles in the open prairie and 1363 in the dense redcedar understory.

Litter accumulation of the understory was quite extensive consisting mostly of redcedar needles and a few cottonwood leaves.

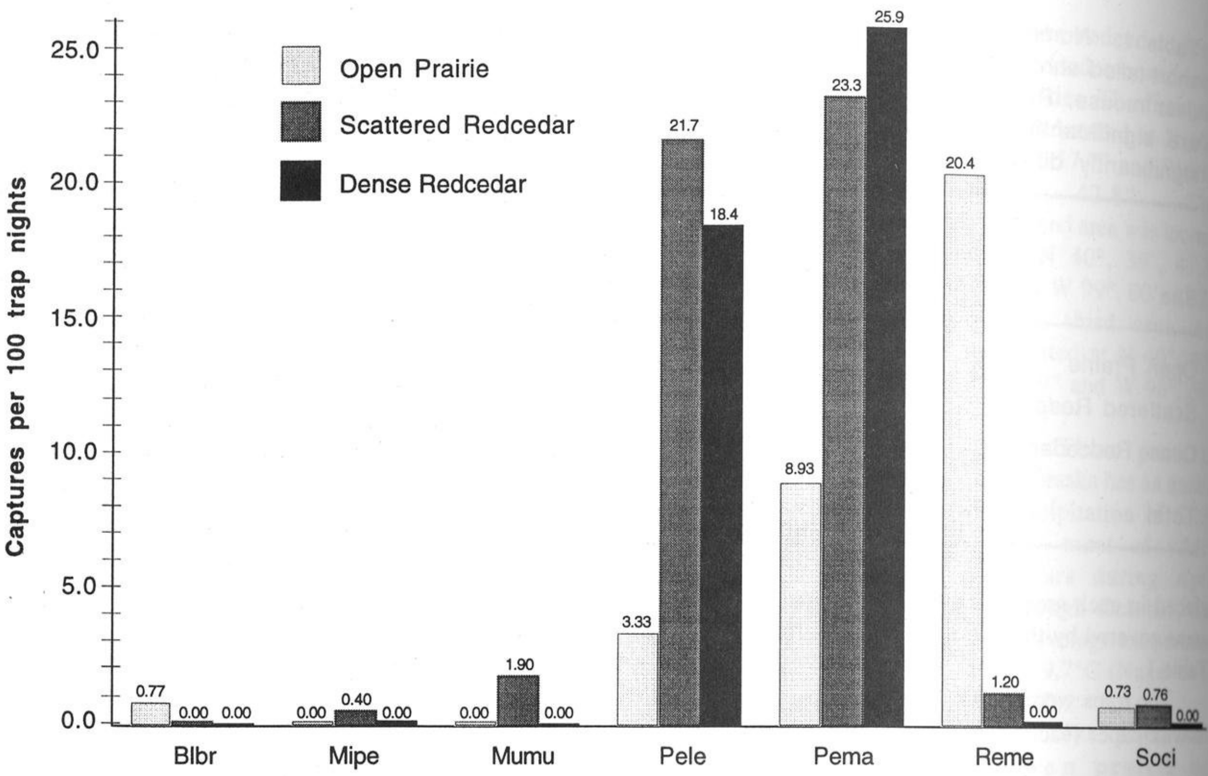

Fig. 2. Capture frequencies (captures per 100 trap-nights) for the Open Prairie, Scattered Redcedar, and the Dense Redcedar habitats. Blbr = short-tailed shrew, Mipe = meadow vole, Mumu = house mouse, Pele = white-footed mouse, Pema = deer mouse, Reme = western harvest mouse, Soci = masked shrew.

Open Prairie

A total of 73 captures was obtained in the open prairie sites (Table 1). This was very nearly the number (73.11) that would have been expected if all habitats had equal captures per total area of habitat. Compared to the scattered redcedar habitat, the total numbers were not significantly different ($P < 0.5$). Also, compared to the dense redcedar habitat, the total numbers were not significantly different ($P < 0.25$).

The capture frequencies of the open prairie sites were greatest for the western harvest mouse (*Reithrodontomys megalotis*) at 20.4%, followed by the deer mouse (*Peromyscus maniculatus*) at 8.9%.

White-footed mice (*Peromyscus leucopus*) had a capture frequency of 3.3%. This surprised us somewhat because the white-footed mouse is typically a woodland inhabitant (Kantak 1996). But trees were never very far away.

The other species caught included both the short-tailed shrew (*Blarina brevicauda*) at 0.8% and the masked shrew (*Sorex cinereus*) at 0.7%.

The analysis of species distribution showed that open prairie had significantly more short-tailed shrews than the other 2 habitats ($P < 0.01$), even though the number was small. There were significantly more harvest mice ($P < 0.001$) as well. There were statistically fewer numbers of white-footed mice ($P < 0.001$), and deer mice ($P < 0.001$) compared to the other habitats.

Scattered Redcedar

A total of 95 captures was obtained in the scattered redcedar sites (Table 1). This was statistically far fewer captures ($P < 0.025$) than would have been expected if all habitats had equal captures per total area of habitat. However, this total was not significantly different from the total for the open prairie sites. Here the deer mouse had the highest capture frequency at 23.3%. This was followed closely by the white-footed mouse with a capture frequency of 21.7%. All other species of small mammals in the scattered redcedar habitat had capture frequencies below 2%: house mouse at 1.9%, western harvest mouse at 1.2%, and the least frequently captured species was the meadow vole (*Microtus pennsylvanicus*) at 0.4%.

The analysis of species distribution when compared to dense redcedar only showed that the scattered redcedar habitat had significantly fewer total captures ($P < 0.01$), as well as fewer white-footed mice ($P < 0.025$).

When compared to open prairie only, there were significantly fewer short-tailed shrews ($P < 0.025$) and harvest mice ($P < 0.001$), and significantly more deer mice ($P < 0.001$) than would have been expected. None of the other differences proved to be statisically significant.

Dense Redcedar

A total of 91 captures was obtained in the scattered redcedar sites (Table 1). This was statistically far more captures ($P < .025$) than would have been expected if all habitats had equal captures per total area of habitat. However, this total was not significantly different from the total for the open prairie sites in comparing just those 2 sites.

Only 2 species were captured within dense redcedar: deer mice and white-footed mice. The average capture frequencies for deer mice was 25.9%. White-footed mice had an average capture frequency of 18.3%.

The analysis of species distribution when the dense redcedar habitat was compared to scattered redcedar habitat only showed that dense redcedar had significantly more total captures ($P < 0.01$), as well as more white-footed mice ($P < 0.025$).

When compared to open prairie only, there were significantly fewer short-tailed shrews ($P < 0.05$) and harvest mice ($P < 0.001$). Also there were significantly more white-footed mice ($P < 0.001$) and deer mice ($P < 0.001$) than would have been expected.

None of the other differences proved to be statisically significant.

CONCLUSIONS

When woody plants invade prairies, it is inevitable that the tree/shrub canopy will result in environmental changes that affect the prairie flora and fauna (Gehring and Bragg 1992). The same holds true for the reverse of this action. When woody plants are removed from a habitat, environmental changes occur. Most of this occurs naturally without human intervention. The changing of flora means the loss of fauna due to death or emigration. In our case, the removal of eastern redcedar would mean a significant loss or emigration of deer mice and white-footed mice.

Mitchell et al. (1995) found high-diversity low-density populations of small mammals within a pine community. But when disturbed, the populations declined in numbers. Their study suggested that in response to management practices of pine communities, the relative abundance of white-footed mice and other species would result in local disappearance. Those species would later recolonize if the habitat were left undisturbed.

Sekgororoane and Dilworth (1995) said that deer mice, short-tailed shrews, and masked shrews are a forest edge species. They based this finding on the fact that these species showed no attraction to or avoidance of the forest edge. Destruction of woodland habitat may result in substantial increase in resource competition among small mammals of the prairie and forest edge by small mammals from the woodland. This could result in the loss of not just 1, but several species.

According to Kantak (1996), white-footed mice are microhabitat specialists in that they only inhabit areas that are more structurally diverse and that have a characteristic of a woodland. Their success in grassy habitats is less than that of their relative, the deer mice, which is a microhabitat generalist. Since most of our captures were of these 2 species (especially deer mice), the removal of the riparian forest could result in the decline of both species.

Since these 2 species serve as food to several other wildlife species (raptors, owls, coyotes, foxes, weasels, various snake species, etc), loosing significant numbers of them might not be desireable from a wildlife management standpoint. Kantak (1996) suggested that such lose could be minimized by introducing some shrub species into the formerly forested area.

Prairie species captured during this sampling consisted of western harvest mice and short-tailed shrews. Both prefer prairie with more than 2 years of litter built up (Springer and Schramm 1972).

Of the 2 species of voles typically found in mixed grass prairie, only the meadow vole was caught in fall 1997. Prairie voles (*Mictotus ochrogaster*) have been caught on this property, just not during this study. Both species prefer some litter buildup, but probably prefer a habitat with more typical prairie grass species and much less Kentucky bluegrass (Springer and Schramm 1972). Removal of the eastern redcedar followed by the seeding of prairie grasses plus the use of occasional fire for management might increase numbers of western harvest mice (Springer 1986) and voles. This could offset the loss of white-footed mice and decline of deer mice.

On the other hand, Foster and Gaines (1990) showed that prairie vole populations negatively affect populations of western harvest mice if successional changes occur in the habitat. Thus, if mangement of the resulting prairie were not done carefully, the small mammal biomass available for predators might not be as great as it was with the redcedars present.

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THE EFFECTS OF LANDSCAPE STRUCTURE ON GRASSLAND BREEDING BIRDS

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Abstract: Grassland birds are declining more quickly than any other group of birds in North America. Breeding grassland birds can be an important beneficiary of prairie conservation and restoration work, but only if certain landscape requirements are met. Many species avoid nesting near habitat components such as hedgerows or other habitat edges that can increase the risk of nest predation and/or brood parasitism. This means that if prairies are going to be managed with grassland birds as an ecological target, they must be kept as free as possible from edge habitats, particularly trees. Clearing trees from the interior of prairie patches can help reduce the threat of nest predation and brood parasitism. More importantly, large patches (over 100 acres) and patches that are more round than linear in shape are much more likely to attract a full complement of grassland breeding bird species. Ongoing research by the author and others is investigating the effects of other edges, including fences, roads, and crop fields on grassland breeding birds.

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Key words: brood parasitism, clearing trees, nest predation, prairie.

Grassland breeding birds are experiencing steeper population declines than any other group of birds in North America. In the midwestern United States, the species showing the greatest drop in numbers include grasshopper sparrows (*Ammodramus savannarum*), western meadowlarks (*Sturnella neglecta*), and bobolinks (*Dolichonyx oryzivorus*). The major hypothesized reasons for these declines include loss of habitat, both in breeding and wintering areas, and fragmentation of remaining habitat.

Recent studies have helped showcase the negative impacts of habitat fragmentation on breeding grassland birds. The first published research on the subject of patch size and grassland birds was by Samson (1980). He noted that several bird species were much less common on small patches of prairie than on larger ones, particularly greater prairie chickens (*Tympanucus cupido*) and upland sandpipers (*Bartramia longicauda*), which bred regularly only in patches larger than 160 hectares. His research served as a stimulus for work by Herkert (1994) and Vickery et al. (1994), who further documented the avoidance of small patches by various grassland bird species. They also put together incidence curves, showing the probability of occurrence for each species based on patch size. Both studies also found that grassland bird species richness was positively related to patch size.

In addition to research on patch size, several researchers have investigated the effects of various patch edges on grassland birds. Johnson and Temple (1990) and Burger et al. (1994) found increased nest predation (and parasitism) near wooded edges. This research provided at least 1 possible reason for the avoidance of small breeding patches by grassland birds: namely small patches failed to provide "core areas," or areas far enough from edges to avoid negative edge effects. Providing further support for the importance of core areas, I studied the effects of both patch size and patch shape on the presence of grassland birds in wet meadows along the central Platte River in Nebraska (Helzer 1996). I found that the perimeter/area ratio of a patch (determined by both patch size and shape) was a stronger predictor of both species richness and the probability of finding a particular species in a patch than was patch size alone. Area-sensitive birds such as upland sandpipers and bobolinks (and to a lesser extent grasshopper sparrows) were more likely to be present in habitat patches that were large and compactly shaped (nearly circular) than in small or linear-shaped patches. Not surprisingly, species richness was also significantly higher in large compactly-shaped patches than in small or linear-shaped patches.

In studies that have estimated the minimum size requirements of species, the results have varied widely for some species but have been consistent for others (Table 1). There are several possible reasons for the disparate estimates, including differences in geographic region, vegetation communities, and local species abundance. The disparity may also result

Table 1. Comparison of minimum patch requirements found in 3 studies (measured by the patch characteristic required to have 50% probability of species presence).

	Patch Size (ha)			Perimeter/Area Ratio (m/m²)
	Herkert 1994 (Illinois)	Vickery et al. 1994 (Maine)	Helzer 1996 (Nebraska)*	Helzer 1996 (Nebraska)*
W. Meadowlark			5	0.024, 0.027
E. Meadowlark	5			
Savannah Sparrow	40	10		
Vesper Sparrow		20		
Grasshopper Sparrow	30	100	8, 12	0.018
Henslow's Sparrow	55			
Bobolink	50		46	0.009, 0.13
Upland Sandpiper		200	50, 61	0.008, 0.007

* Multiple numbers represent results that differed between years.

from differences in the shape of patches used in each study, as well as the abundance and relative proximity of habitat patches in each study area. Much more research is needed where both size and perimeter/area ratio requirements are estimated in order to understand habitat requirements of grassland birds in different parts of their ranges. One important note, however, is that despite the differences in specific minimum size requirement estimates between studies, the relative size requirements between species was generally consistent (upland sandpipers and bobolinks were found to need larger areas than were grasshopper sparrows and meadowlarks).

In 1996, I began preliminary investigation into the reaction of grassland birds to various habitat patch edge types (Helzer 1996). I found that grasshopper sparrows and bobolinks were much less common near patch edges adjacent to woodlands than closer to the center of the patch, and that grasshopper sparrows were similarly less abundant near crop fields edges. Other species were not sufficiently numerous in my study patches to measure a response. There was no apparent avoidance of "two-track" gravel roads, although I did not investigate the effects of wider, more traveled, gravel and paved roads. I measured responses to edges only by the location of perched birds, not by nest location, which would have provided better data.

As a next step, I have just started to look at the effects of fencelines. Interestingly, I found that in cases where favorable bobolink habitat is bisected by a fence, male bobolinks seem to use fencelines as territory boundaries. Males with a territory on 1 side of the fence, when repeatedly flushed, would land on perches on their side of the fence, and often on the fence itself, but would not land on the opposite side, where another male is typically on territory. The only exception to the rule is that males will invariably chase a female that flies across the fence into a neighboring territory, although even then the outsider male rarely lands in the neighbor's territory. However, despite the obvious recognition of the fence as a dividing structure, bobolinks do not seem to be any more or less abundant near fencelines than in the center of pastures.

Of the other species I have looked at so far, the dickcissel appears to be unaffected by the fencelines, except that fences are often favored perch sites. I am continuing to look at the response of other species.

My next step will be to investigate the effects of fencelines that divide prairies into management units of drastically different vegetation structure (idled field vs heavily grazed pasture, etc.) to see if these edges negatively impact bird use of areas proximate to the fences. The results of this next step will be particularly interesting because many of the meadows managed by The Nature Conservancy and other conservation groups along the central Platte River are divided in this manner.

Implications to Prairie Conservationists

Because of population declines, grassland birds have become important ecological targets for prairie conservationists. Although some species (notably dickcissels) are probably in greater need of protection in their wintering grounds than in breeding areas, others (such as Henslow's sparrows) may require specific types of habitat in their breeding areas to avoid local extirpations.

Besides being the targets of conservation efforts for their own sake, grassland birds can sometimes be used as 1 of a suite of indicators of prairie quality. The number of grassland breeding bird species in a prairie is relatively easy to ascertain simply by taking a morning walk during the breeding season. Because a large area with a variety of vegetation structure is needed to maintain a full complement of grassland bird species, the number of grassland bird species present on a property or group of properties can be used as a measure of the range of habitats being provided for a number of other animal species. However, as shown by the abundance of grassland birds in Conservation Reserve Program (CRP) plantings, grassland birds do not necessarily require high plant species diversity in their nesting habitat. They also appear to be generalists in their food selection. Thus they can not be relied upon as good indicators of plant or insect diversity.

Based on the results of recent grassland bird research projects, there are a number of recommendations for those charged with managing grassland birds in fragmented environments:

1. Provide large, compactly shaped patches (minimize perimeter/area ratio) whenever possible. Restoration of adjacent land can enlarge small patches.
2. Clear trees from the interior of small or narrow patches, and from patch edges where appropriate, to maximize available habitat.
3. Provide a variety of vegetation structure within a landscape, making each discrete management unit as large as possible. Assess the vegetation structure available on nearby properties and try to fill in gaps that exist (i.e. large patches of prairie that have been idle for at least 1 season are often missing in landscapes that are dominated by private ownership). Rotate management on any 1 unit to avoid managing against plant and other species not adapted to a particular management regime.
4. When possible, divide management units by non-permanent boundaries, such as electric fence, that can be relocated periodically to avoid creating edges within patches.
5. Carry out simple monitoring of species presence and abundance, as well as periodic checks of predation and parasitism rates if possible.

CONCLUSIONS

There is still much to learn about the effects of habitat fragmentation on grassland birds. For example, no research on minimum patch size or perimeter/area requirements has taken place in short grass or mixed-grass habitats. Estimates of patch size and shape requirements are also needed in other parts of the tallgrass prairie to increase our understanding of the reasons for the avoidance of small or linear patches by some species. More work is needed on predation and brood parasitism rates near different kinds of patch edges, as well as the response of nesting birds to those and other pressures. Research is also needed to investigate the importance of other landscape measures including nearest neighbor, contagion, etc. Also, no significant work has been published on the habitat patch qualities needed by migrating grassland birds.

At this point, the research that has been done indicates that large patches which provide core areas (free from edge effects) for nesting habitat may be crucial for the conservation of some species of grassland birds. As prairie conservation efforts continue to gain momentum, it will be important to provide not only a variety of patches that meet vegetation structure requirements for birds, but patches that meet their landscape requirements as well. At this point we have not lost any grassland birds to extinction, but the rate of population decline of some species shows that we may have to act quickly to maintain that record.

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ECOREGIONAL CONSERVATION IN THE GREAT PLAINS

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Abstract: In 1995, The Nature Conservancy refocused its organizational framework and set its conservation goal as "the long-term survival of all viable native species and community types through the design and conservation of portfolios of sites within ecoregions." The Conservancy has identified 15 ecoregions that will provide structure for ecoregional conservation in the Great Plains. To date, conservation planning has been initiated in 7 Plains ecoregions; all 15 will be completed by the year 2003. These efforts are utilizing biodiversity data from Natural Heritage Data Center programs and other sources, satellite imagery, and an array of additional tools to identify conservation targets, set ecoregional conservation goals, and identify the suite of sites that will ensure the long-term viability of all native species and natural communities. Two Plains ecoregions (Northern Tallgrass Prairie and Central Shortgrass Prairie) have completed plans in place. Successful implementation of these plans, however, will be a huge undertaking requiring the cooperation of all stakeholders.

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Key words: biodiversity, Central Shortgrass Prairie, Natural Heritage Data Center, Northern Tallgrass Prairie, The Nature Conservancy

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The Nature Conservancy has been an advocate of biodiversity conservation since its inception in 1951. Since that time, however, its strategies for identifying areas for conservation action have evolved significantly as scientific models and approaches to conservation have improved. In the early years, conservation action was driven primarily by opportunity or on the opinion of local experts; there was little ability to compare the "biological value" between, and subsequently prioritize, potential conservation sites. This changed significantly in the 1970s with the development of the Natural Heritage Data Center Network and its strategic focus of inventorying and tracking the status of natural communities and imperiled species within a given state or jurisdiction. Only then was it possible to strategically target the highest quality occurrences of a given species or natural community type for conservation action. However, improvements in the identification of areas for conservation action continue to be made, the most recent relating to ecoregional conservation.

In November 1995, The Nature Conservancy laid out its organizational vision (The Nature Conservancy 1996a). This document set forth a new conservation goal for the organization which was succinctly stated as "the long-term survival of all viable native species and community types through the design and conservation of portfolios of sites within ecoregions." The conservation targets that would enable fulfillment of this goal were identified as "all viable native community types and all viable vulnerable native species." The use of ecoregions (large geographic areas with similar climate and landform) as planning units ensures that conservation targets are addressed within an ecological context.

In recent years, initiatives such as the Conservancy's Great Plains and Great Lakes programs have enabled large-scale assessment and conservation planning through the assembling of Natural Heritage Data Center element occurrence data bases from the states and provinces in their respective regions (Ostlie et al. 1997, The Nature Conservancy Great Lakes Program 1994). These programs have facilitated ecoregional conservation within the organization, assisting with the development of conservation strategies, serving as a resource for sharing information and best practices between planning teams, and in the case of the Great Plains Program, tackling problematical issues that could not be efficiently addressed at the scale of an ecoregion (e.g., migratory birds).

What follows is a summary of the ecoregional conservation process as it has developed in the Great Plains. Because of the relative homogeneity of the region (e.g., similar climate, flora and fauna,

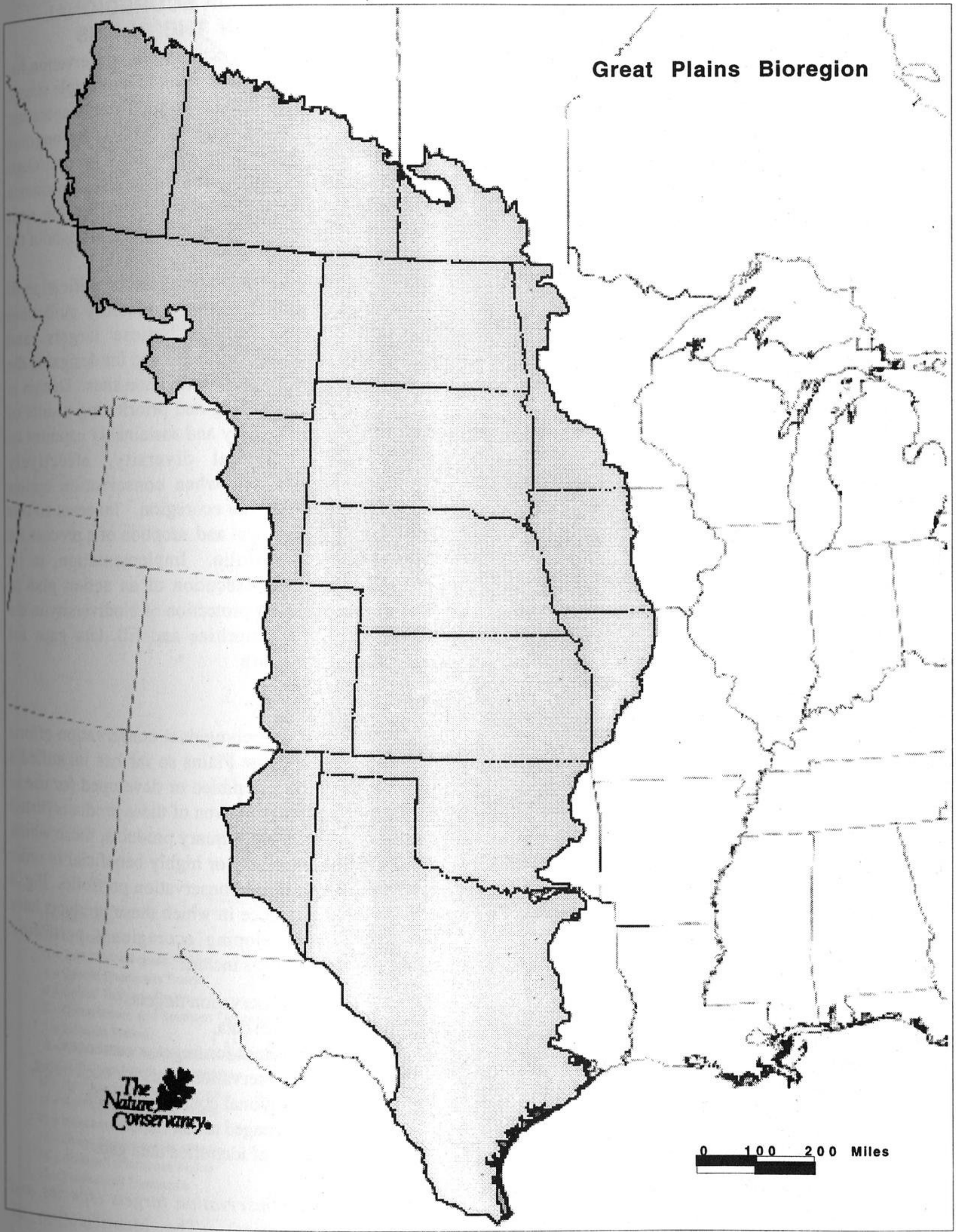

Fig. 1. The Great Plains Bioregion as designated by The Nature Conservancy. Map created by TheNature Conservancy, Midwest Conservation Science Department. © July 1998, The NatureConservancy.

geological strata, history, and socio-economics), many of the strategies and tools for assembling portfolios of conservation sites have been shared between teams working in Plains ecoregions. However, even in a region with many uniformities, each ecoregion brings with it a set of unique issues and problems that ultimately require an ecoregion-specific modification to the process.

BACKGROUND

The Conservancy has identified 63 ecoregions that provide structure for ecoregional planning in the United States (The Nature Conservancy 1996b). The Great Plains, as delineated by The Nature Conservancy (Ostlie et al. 1997), occupies 2.6 million km^2 (1 million mi^2) within the center of North America (Fig. 1), and comprises 15 ecoregions, ranging from the Tamaulipan Thornscrub in south Texas and adjacent Mexico north to the Fescue Prairie/Mixed-grass Aspen Parkland of Canada (Fig. 2). Although predominantly flat to rolling terrain, the Plains bioregion also include isolated mountain ranges, plateaus, mesas, badlands, canyons and sandhills. The dominant vegetation of the region includes tallgrass prairie in the east, mixed-grass through the central and northwest, and shortgrass prairie in the southwest. An area of acacia shrub/savanna dominates the south Texas Plains region (Ostlie et al. 1997).

The ecoregions of the Great Plains were largely adapted from Bailey (1995) and the Ecological Stratification Working Group (1995) for the United States and Canada, respectively. Canadian ecoregional lines should be considered tentative until final boundaries are cooperatively set by The Nature Conservancy and Canadian scientists.

Ecoregional conservation in the Great Plains was initiated in November 1995 with the assembly of a core team for the Northern Tallgrass Prairie (NTP) ecoregion. The Central Shortgrass Prairie (CSP) and Northern Great Plains Steppe (NGPS) ecoregions followed suit in 1996. As of summer 1998, ecoregional conservation has been initiated in 7 of 15 Plains ecoregions (Fig. 2). Two ecoregions, the CSP and NTP, have completed the first iteration of their respective conservation portfolios. Two additional ecoregions (NGPS and Central Tallgrass Prairie [CTP]) are likely to finalize their conservation portfolios in late 1998 or early 1999. All ecoregional plans in the Plains and across the United States are expected to be completed by 2003.

THE STRUCTURE OF ECOREGIONAL CONSERVATION IN THE PLAINS

In the Great Plains, ecoregional conservation has been conceptualized as occurring in 3 principle stages: (1) assessment, (2) design, and (3) implementation (Fig. 3). Each stage is envisioned as an ongoing process within a larger iterative effort that, through time, will be refined as new information becomes available. Information needed to refine the next iteration ecoregional plan is identified throughout the planning process.

Assessment has as its goal the identification of conservation targets, setting of viability guidelines and conservation goals for those targets, and assemblage of the base data required for designing the ecoregional portfolio of conservation sites. Design is the process of assembling and prioritizing a suite of sites that most efficiently and sustainably captures an ecoregion's biological diversity, effectively identifying where and when conservation action should occur within the ecoregion. Inherent to this stage is the development and adoption of a process for assembling the portfolio. Implementation, in its purest sense, is the execution of an action plan to address the long-term protection of biodiversity in the ecoregion, and to prioritize and fill data gaps for critical future iterations.

Assessment

Analysis of the ecoregional conservation efforts underway in the Great Plains so far has identified a series of products assembled or developed for use in the later design stage. Seven of these products (listed below) are considered primary products, those which are absolutely necessary or highly beneficial in order to achieve a successful conservation portfolio. Fig. 4 illustrates the sequence in which these products have been used in developing ecoregional portfolios. These primary products include:

1. Ecoregional conservation targets.
2. Target occurrence data.
3. Viability guidelines for target occurrences.
4. Ecoregional conservation goals for each target.
5. Potential ecoregional conservation sites.
6. Ecoregional managed areas.
7. Documentation of identified data gaps.

Ecoregional conservation targets (species and natural communities).—The identification of conservation targets determines the species and natural communities around which an ecoregional portfolio

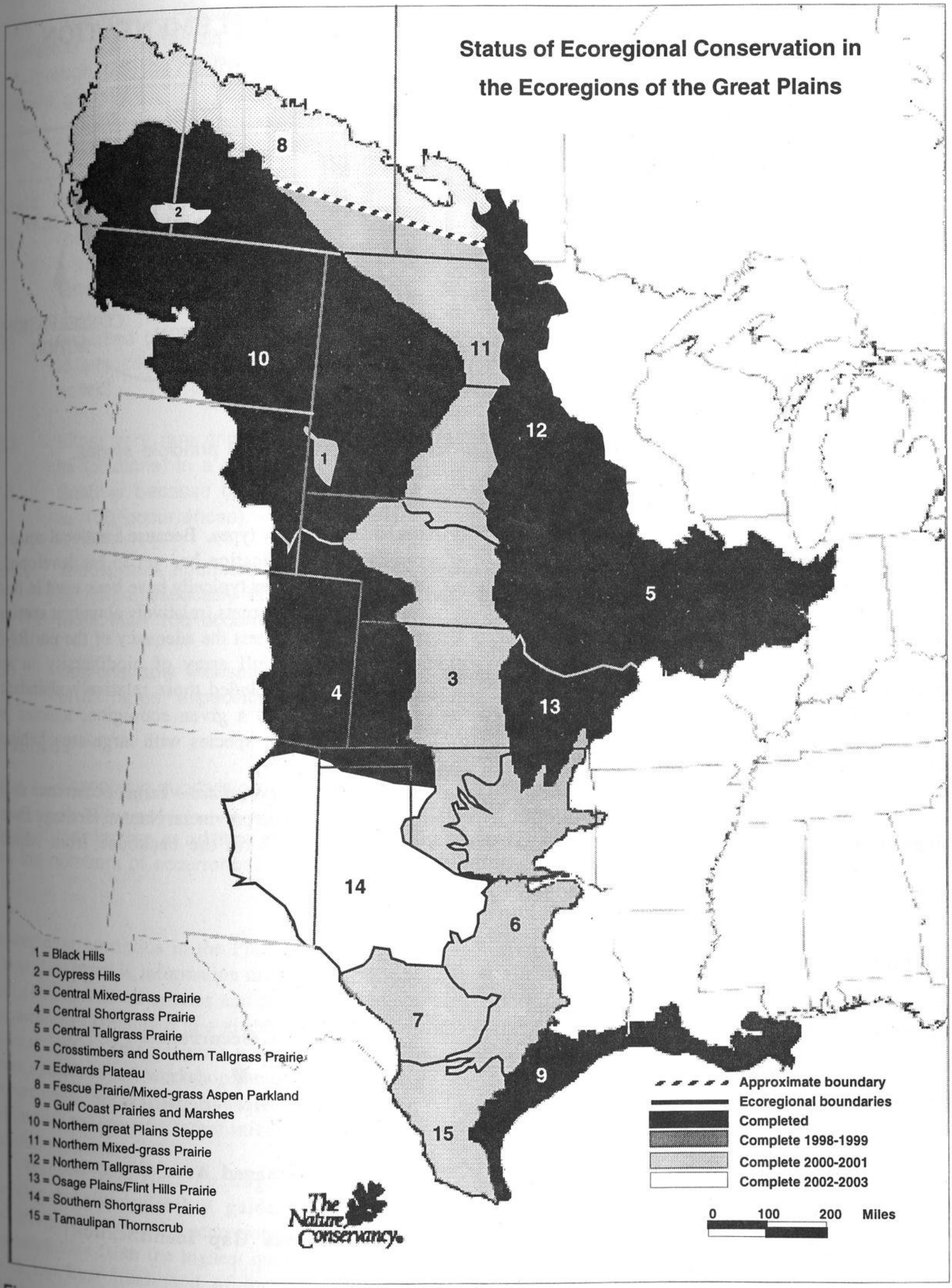

Fig. 2. Status of ecoregional conservation in the Great Plains. Map created by The Nature Conservancy, Midwest Conservation Science Department. © July 1998, The Nature Conservancy.

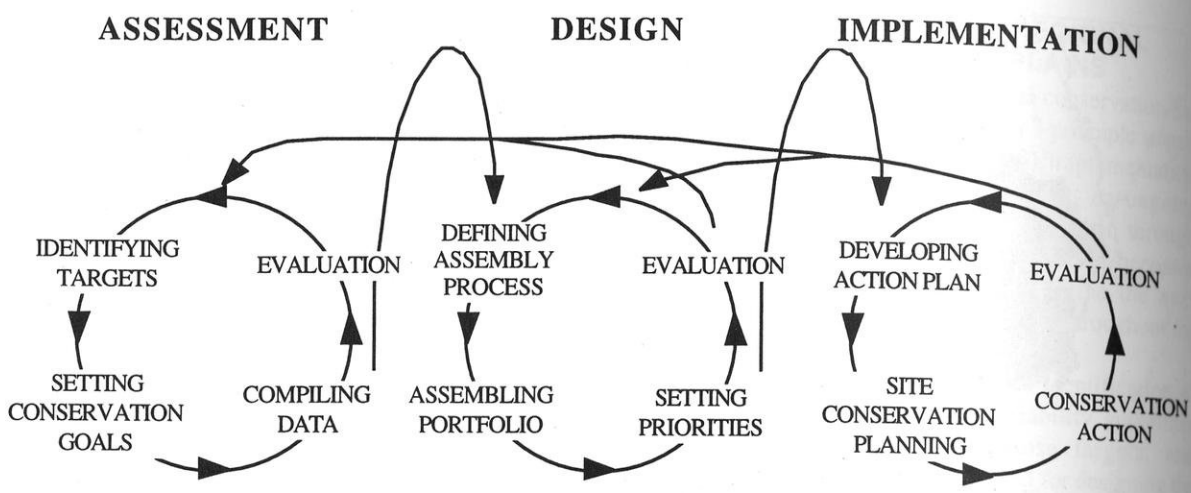

Fig. 3. Ecoregional conservation conceptualization illustrating the 3 principle stages.

of conservation sites is assembled. Primary targets for ecoregional conservation in the Plains have typically included all natural community types (both terrestrial and aquatic) and all G1-G3/T1-T3 and federally listed or candidate species with occurrences in a given ecoregion (Table 1). Terrestrial community types for each ecoregion were identified from a natural vegetation classification system developed by the Conservancy and its Natural Heritage Data Center partners (Grossman et al. 1998). In ecoregions with little natural community data from which to derive a portfolio, more generally described ecological complexes have been used in place of standard community types. Because a national aquatic community classification has yet to be developed, surrogate approaches typically have been used in this arena. Secondary targets (relatively abundant species used principally to test the adequacy of the portfolio in capturing the full array of biodiversity in an ecoregion) have included those relatively abundant species endemic to a given ecoregion, species in general decline, or species with large-area habitat requirements.

Target occurrence data.—Target occurrence data from respective state/provincial Natural Heritage Data Center programs form the backbone from which

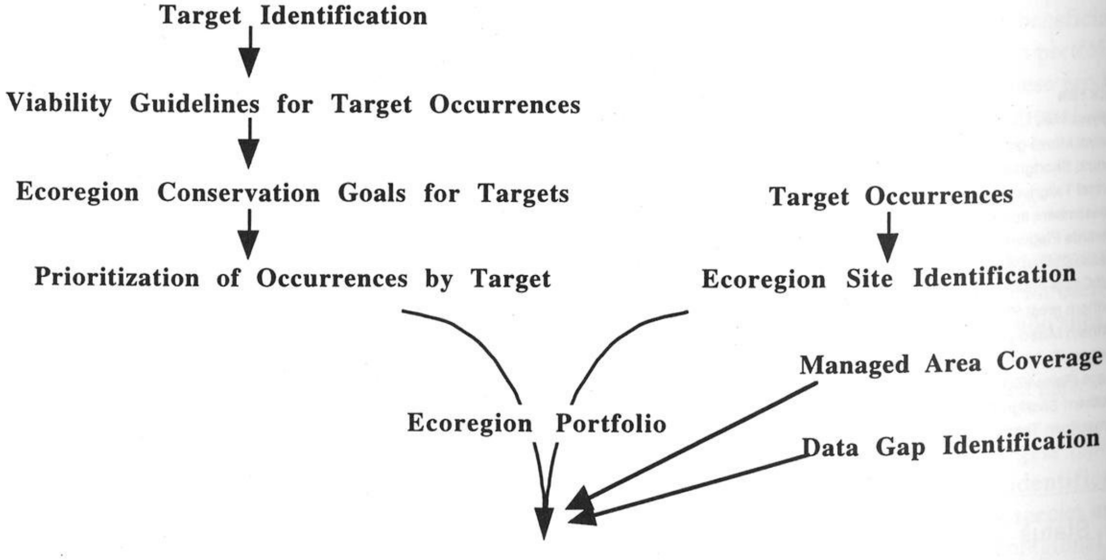

Fig. 4. Ecoregional assessment.

Table 1. The Natural Heritage Data Center Network ranking system. The Global Rank of an element of biodiversity is assigned on the basis of the following definitions. G# = Numeric rank: A numeric rank (G1 through G5) of relative endangerment based primarily on the number of occurrences of the element globally.

Rank	Description
Basic Ranks	
G1	Critically imperiled globally because of extreme rarity or because of some factor(s) making it especially vulnerable to extinction. (Typically 5 or fewer occurrences or very few remaining individuals or acres).
G2	Imperiled globally because of rarity or because of some factor(s) making it very vulnerable to extinction throughout its range. (6 to 20 occurrences or fewer remaining individuals or acres).
G3	Either very rare and local throughout its range or found locally (even abundantly at some of its locations) in a restricted range (e.g., a single western state, a physiographic region in the East) or because of other factors making it vulnerable to extinction throughout its range. (21 to 100 occurrences).
G4	Widespread, abundant, and apparently secure globally, though it may be quite rare in parts of its range, especially at the periphery. Thus, the Element is of long-term concern. (Usually more than 100 occurrences).
G5	Demonstrably widespread, abundant, and secure globally, though it may be quite rare in parts of its range, especially at the periphery.
Subrank	
T	Taxonomic subdivision: rank applies to a subspecies or variety.

Note: Other factors in addition to the number of occurrences are considered when assigning a rank, so the numbers of occurrences suggested for each numeric rank above are not absolute guidelines.

ecoregional portfolios in the Plains are assembled. These data provide information on the location, size, and condition of all species and natural community occurrences inventoried in a given state or province (Morse 1993). In ecoregions where inventory data were sparse, expert workshops and rapid ecological assessments have been used to quickly gather additional site-specific target information for use in portfolio assembly.

Viability guidelines for target occurrences.—Setting baseline viability guidelines for target occurrences is essential if ecoregional portfolios are to be assembled from the highest quality occurrences with the best likelihood of long-term viability. When available, Element Occurrence Ranking Specifications (a component of the Conservancy's Biological Conservation Database) were used as the primary means of assessing target occurrence viability. These ranking specifications are developed in a global context and are based on a knowledge of historic evidence and current status, and include threshold values for assigning quality ranks to target occurrences. As such, these occurrence ranks provide a succinct assessment of predicted viability based on condition, size, and landscape context (The Nature Conservancy 1997), and enable a meaningful comparison of all occurrences of a given target across the ecoregion and throughout its range.

Ecoregional conservation goals for each target.—Conservation goals set both the number and geographic distribution of viable occurrences required for the long-term viability of each target species and community type, both across the full range of the target (Rangewide Conservation Goals) and within the

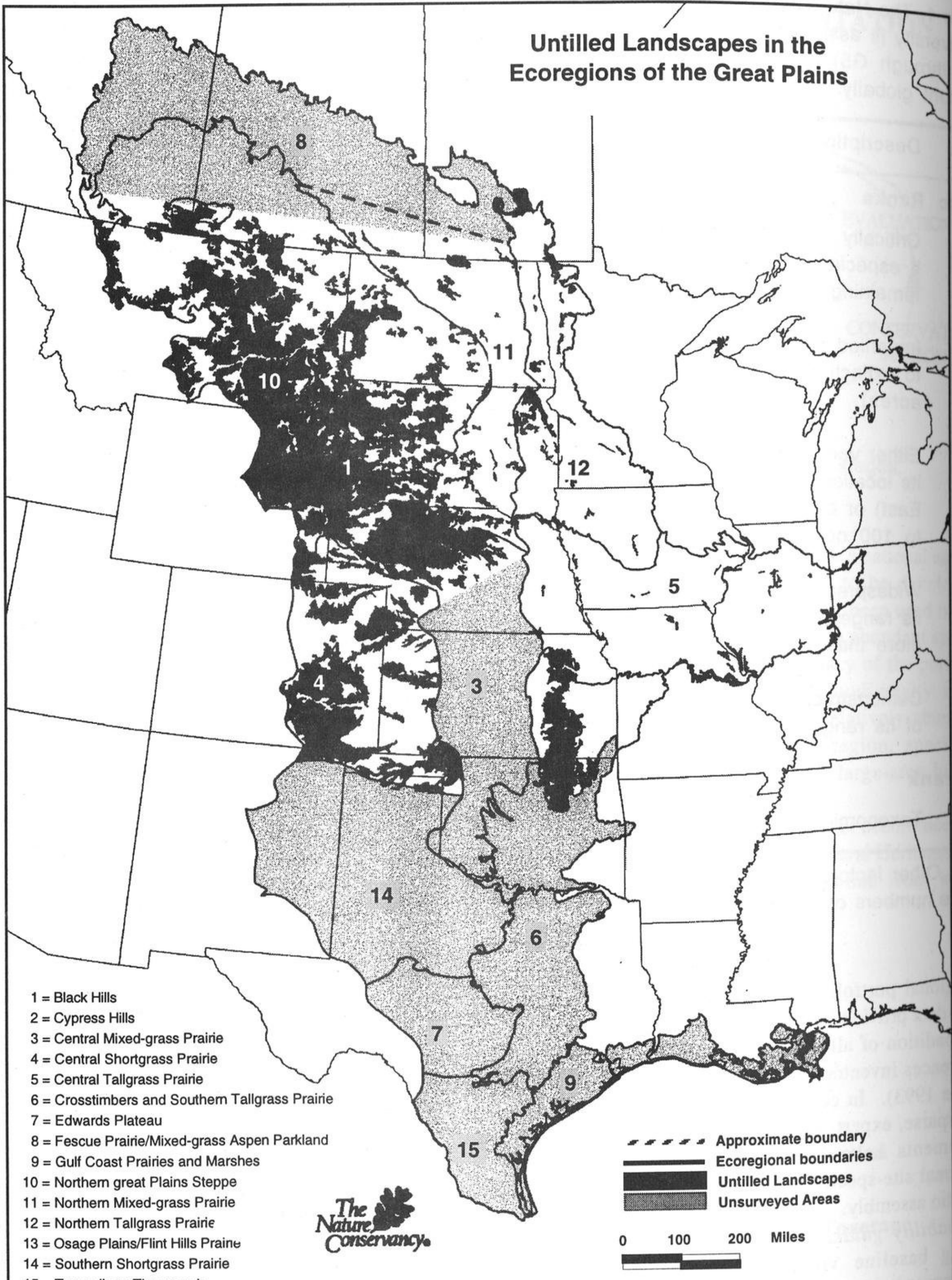

Fig. 5. Untilled landscapes of the Great Plains. Map created by The Nature Conservancy, Midwest Conservation Science Department. © July 1998, The Nature Conservancy.

ecoregion (Ecoregion Conservation Goals). Ecoregion goals are based on rangewide goals, and as such, require an assessment of the ecoregion relative to the rangewide distribution of each target. Rangewide and ecoregion goals typically have been based on scientific theory and published and unpublished data.

Potential ecoregional conservation sites.—Target occurrence, expert workshops, and rapid ecological assessment data, along with satellite Thematic Mapper (TM) imagery, identify the full suite of sites from which a given ecoregional portfolio is assembled. Satellite TM imagery with a ground resolution of 30 m (100 ft) has been used in each of the Plains ecoregions that have initiated ecoregional conservation to date as a means to identify large, untilled areas (landscapes) exceeding 65-130 km^2 (15-50 mi^2) in size (Fig. 5). These untilled landscapes have been used to assess the ecological context of target occurrences. Landscapes are more likely to maintain large-scale processes than are smaller areas, and as such enhance the potential for long-term target occurrence viability (Chaplin et al. 1996). In addition, landscapes of this size may be large enough to sustain viable examples of matrix community types (those that covered large geographic portions of an ecoregion) and populations of species with large habitat requirements. Because of their potential for enhancing the long-term viability of target occurrences, untilled landscapes frequently were used to prioritize where rapid ecological assessments would occur within an ecoregion.

Ecoregional managed areas.—As a component of ecoregional assessment, it has been beneficial to identify those managed areas that offer some minimum level of long-term protection to biodiversity. This data layer enables a characterization of the level of conservation work already underway in ecoregional portfolio sites, but is perhaps most useful in site-specific conservation planning.

Documentation of identified data gaps.—Data gaps preclude the optimal development and implementation of an ecoregional plan. However, the iterative nature of ecoregional conservation enables the Conservancy and its partners to identify, prioritize, and fill critical data gaps within the ecoregion in a timely and strategic manner. As a step toward that end, data gaps are identified throughout the ecoregional conservation efforts, compiled, and prioritized for future action.

Design

The biodiversity of the Great Plains is intricately tied to the natural processes with which it evolved (i.e., fire, grazing, and climate). Because long-term viability of occurrences is tied to these large-scale processes, a portfolio assembly process with a weighted focus on ecological context was first developed for the Northern Tallgrass Prairie ecoregion (The Nature Conservancy Northern Tallgrass Prairie Ecoregional Planning Team 1998). Modified versions of this assembly process have been used in each of the 3 subsequent Plains ecoregions that have assembled conservation portfolios to date (i.e., CSP, NGPS, and CTP), reflecting the unique set of attributes each possesses. It should be noted, however, that other innovative portfolio assembly methodologies (perhaps very different from these) may be developed for future Great Plains ecoregional conservation efforts, much as they have been used in other parts of the country. The discussion of this specific process should not be construed to mean that this is the only assembly process applicable in the Plains or being utilized by the Conservancy.

The generalized ecoregional portfolio assembly process used in the Plains includes 4 distinct rounds of selection and refinement (Fig. 6). Ecological context is factored into the assembly process in 2 ways:

1. Target occurrences with excellent and good predicted viability are incorporated into the portfolio before lesser-viable examples. Because a primary factor in ranking occurrences is landscape context, target occurrences within a good landscape context were likely to be incorporated before those in poorer settings.

2. The portfolio selection sequence places emphasis on natural communities (selecting occurrences of communities before species), and within natural communities on types which historically dominated the landscape (i.e., matrix-forming types).

Sites of sufficient size to sustain viable examples of matrix communities are inherently larger and likely to encompass viable examples of large and small patch communities and most species.

Round 1 of portfolio assembly: selection of primary target occurrences with excellent-good predicted viability potential.—Within the first round of selection, priority was given to high-quality occurrences of conservation targets. This served to equalize the playing field between targets by assuring that selections of high quality occurrences were made

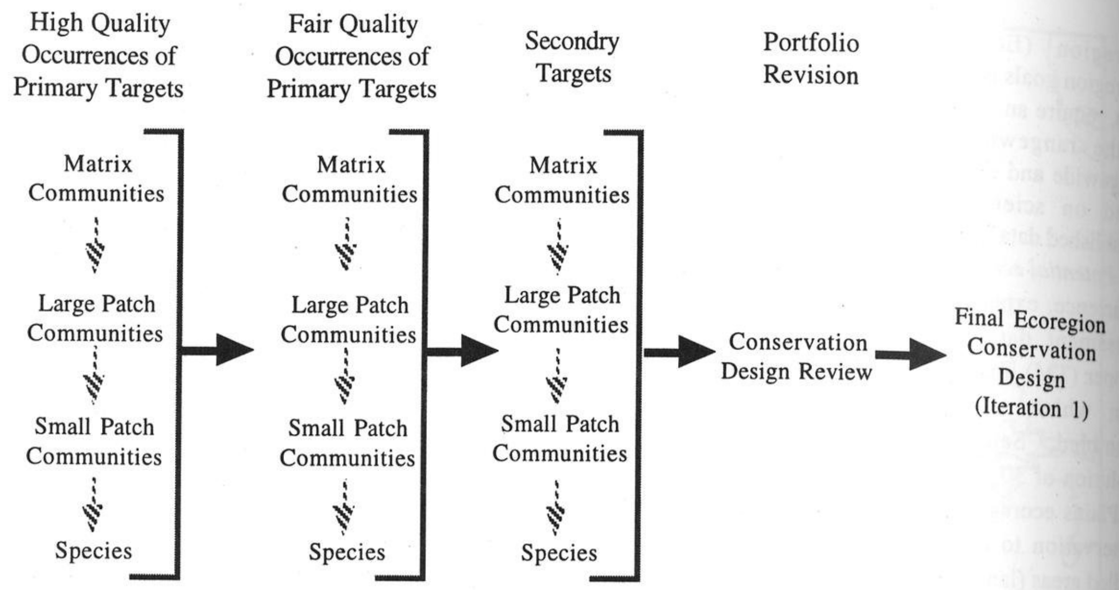

Fig. 6. Portfolio assembly sequence.

for all targets before ones of lesser quality were incorporated into the portfolio.

Round 2 of portfolio assembly: selection of primary target occurrences with fair viability potential.—Due to the highly fragmented nature of some Plains ecoregions, it was imperative that a process be developed to capture lesser quality occurrences if few if any high quality examples remained. Target occurrences of fair quality were not used to satisfy ecoregional conservation goals due to their marginal level of viability, but their presence in the portfolio would effectively serve as a "life raft." Through proper management and restoration, the viability of these occurrences may be enhanced. Upon completion of this round, a draft ecoregional design for all primary targets was completed.

Round 3 of portfolio assembly: assessment of the preliminary portfolio and selection of secondary target occurrences.—In order to meet the Conservancy's conservation goal in a given ecoregion, it is necessary to assess the adequacy of the conservation portfolio in capturing sufficient populations of the full array of common species. If insufficient numbers of secondary target occurrences were captured in the portfolio assembled for primary targets, this round enabled additional site selections to fill those gaps.

Round 4 of portfolio assembly: Reassessment and Critical Review of the Portfolio Design.—A final assessment and critical review of the draft ecoregion portfolio design allowed for modifications based on scientific rationale and feasibility analyses.

Selection within rounds.—Within each of the first 3 rounds of portfolio assembly, selection of target occurrences was addressed in the following group sequence: matrix community, large patch community, small patch community, and species (i.e., selections were made for all matrix community targets before any for large patch, small patch or species targets).

Selection group 1: matrix communities.—Matrix communities were the characteristic vegetation types of the ecoregion. Single occurrences of these types covered vast acreages (> 809 ha [2000 acres]) in a more-or-less continuous pattern. Their presence on the landscape was dependent upon regional-scale processes now perhaps found only at the largest sites in an ecoregion (if at all). As a result, viable sites selected for these targets are likely to be the largest in the portfolio. The long-term viability of all targets is enhanced within large-scale functioning systems.

Selection group 2: large patch communities.—Large patch communities were the moderate-sized types on the landscape, forming discrete patterns within the dominant matrix backdrop. Individual occurrences of these communities typically ranged from 20-809 ha (50-2000 acres). Their presence on the landscape was dependent upon local-scale processes. The viability of occurrences is heightened within large landscapes. However, viable sites for large patch communities (even if not within a landscape setting) retain some level of system functionality that enhances the viability of small patch communities and the many species that may be found within them.

Selection group 3: small patch communities.—Small patch communities were the very small-sized types, with individual occurrences of less than 20 ha (50 acres) embedded within the larger matrix and large patch types. Their presence on the landscape was largely dependent upon very local, isolated processes and factors. The viability of occurrences is enhanced within larger systems (i.e., sites identified for matrix and large patch communities); however, small patch community viability requirements also may be met at sites too small for large patch and matrix types.

Selection group 4: species.—Species are dependent upon the community types within which they occur, although from a natural community standpoint these may range from being high-quality to degraded. Irrespective of this, species occurrence viability is contingent upon many of the same natural processes (or those mimicked by humans) under which communities evolved.

Modifications to this generalized model have been commonplace. In the CTP, for example, aquatic communities were addressed in the first round after terrestrial communities, but before species. In the CSP and NGPS, aquatic communities were addressed at the close of the first round. In addition, no second round was undertaken in the CSP due to the low level of biological inventory undertaken in the ecoregion; it is likely that significant numbers of target occurrences with excellent and good predicted viability remain undocumented. In the NGPS, the general low level of inventory effort throughout the ecoregion mandated a significant deviation from the generalized process. Generally described ecological complexes were used as surrogates for more specific terrestrial community types. Because detailed occurrence data were available for many of the ecoregion's imperiled species, site selection was initiated with this group. Also, the entire untilled landscape coverage was included into the portfolio as an ecological backdrop, stressing the need to undertake broad-scale actions beyond the borders of the portfolio sites and throughout the ecoregion.

Resulting conservation portfolios.—Four ecoregions have compiled conservation portfolios in the Great Plains to date: 2 are final and 2 are in draft stages of development. A comparison of these 4 ecoregional portfolios follows.

Table 2. Results of ecogregional portfolio assembly for 4 ecoregions.

Characteristic	Northern Tallgrass Prairie	Central Shortgrass Prairie	Northern Great Plains Steppe[a]	Central Tallgrass Prairie[a]
Number of Targets				
Terrestrial Communities	98	94	323 (34[b])	99
Primary Species	25	54	41	66
Conservation Goals Fully Met				
Terrestrial Communities	9	8	(7[b])	12
Primary Species	4	13	14	9
Total Selections Available/Met				
Terrestrial Communities	362 / 130	NA	420 / 290	436 / 149
Primary Species	72 / 43	NA	150 / 68	203 / 95
Number of Portfolio Sites	66	71	127	251
Area of Ecoregion (km²)	189,441	231,805	642,138	285,883
Area of Ecoregion (mi²)	73,143	89,500	247,929	110,379
Percent of Ecoregion within Portfolio Sites	0.03	0.22	NA	NA

[a] Based on draft reports.
[b] Ecological complexes (assemblages of community associations) were used as a surrogate for terrestrial community targets.

Meeting target conservation goals.—An assessment of the 4 ecoregional portfolios clearly illustrates that the majority of target conservation goals were not met in any of the 4 ecoregions; this holds true for species and natural communities alike (Table 2). With the exception of the NGPS, goals were fully met for less than 13% of the natural community types in each ecoregion portfolio. The larger percentage of goals being fully met in the NGPS (20.6%) may be an artifact of its use of ecological complexes rather than the finer-scale association-level community classification used in other ecoregions. In each ecoregion, greater percentages of species than communities were fully captured, ranging from a low of 13.7% in the CTP to a high of 34.1% in the NGPS.

Although these numbers appear low, they do not fully reflect the true number of selections made toward meeting target conservation goals. When the total number of selections made for targets is measured against their respective ecoregional conservation goals, a more accurate picture emerges. In the 3 ecoregions reporting these data, 34% to 72% of all possible selections for terrestrial communities were made. Again, the relatively high percentage of selections made in the NGPS may be an artifact of its use of ecological complexes. Like terrestrial communities, species selections accounted for 45% to 60% of those available.

Still, it is evident that major gaps exist in our current ability to fully address the needs of all conservation targets in a given ecoregion. In the Plains, this is due to 2 dominant reasons: (1) insufficient inventory, and (2) whole-scale conversion or degradation of habitat in entire ecoregions or portions thereof.

In the tallgrass ecoregions of the eastern Plains, intensive inventory has been conducted for most imperiled terrestrial community types and species. However, little information is available to guide site selections for many of the common community types. In addition, the near-complete conversion of the tallgrass ecosystem has lead to an inability to identify sufficient high-quality occurrences to meet the conservation goals established for many of the targets (The Nature Conservancy Northern Tallgrass Prairie Ecoregional Planning Team 1998).

Relative to the eastern Plains, western Plains ecoregions still retain large landscape-scale areas of untilled land (Fig. 5). However, as a general rule, little inventory has been conducted in these ecoregions, particularly for natural communities. Also, despite the relative abundance of large untilled landscapes, the distribution of these tracts within these ecoregions is not uniform. In the CSP, for example, the large proportion of remaining landscapes are dominated by sandsage communities, much of the historical shortgrass prairie having been converted to agriculture (The Nature Conservancy Central Shortgrass Prairie Ecoregional Planning Team 1998). Similarly, relatively few untilled landscapes remain in the northern, glaciated portions of the NGPS, making identification of occurrences of some community types in that portion of the ecoregion problematical.

The number of portfolio conservation sites.—The total number of portfolio conservation sites identified in the four ecoregions varies between a low of 66 in the NTP to a high of 251 in the CTP (Table 2). These specific numbers do not carry a lot of weight since a large percentage of target conservation goals have not been met. In addition, differences in ecoregion size and the degree to which target conservation goals were met in an ecoregion further cloud the picture. However, some trends are worth noting.

The large number of portfolio sites in the CTP is a reflection of the severe level of conversion of natural habitat in that ecoregion. Those natural areas remaining are nearly universally small (<100 acres) and seldom capture more than 2-3 target occurrences of conservation goal quality. Conversely, portfolio sites in the CSP and NGPS tend to be significantly larger than those in the east, frequently capturing an array of conservation targets. As a result, fewer sites per unit area are required to make a conservation contribution to the portfolio equal to that of more fragmented ecoregions. An apparent anomaly to this trend is the NTP which was able to make a portfolio conservation contribution equal to the CTP with roughly 25% of the total number of sites. However, a number of relatively large untilled landscapes still remain in the NTP, several of which captured more than 10 target occurrences selected to meet ecoregional conservation goals.

Perhaps more interesting, however, is the land area captured by existing ecoregional portfolios. As stated previously, site size in western Plains ecoregions is significantly larger than those in the tallgrass ecoregions. This fact is borne out in a comparison of the CSP and NTP ecoregions, 2 ecoregions of roughly similar size with approximately the same number of conservation targets. Results of their respective ecoregional conservation portfolios showed similar results, both in terms of the degree to which conservation goals were fully met and the total number of portfolio sites.

Yet, the CSP portfolio captured 22% of the ecoregion compared with 3% for the NTP.

Implementation

All conservation areas in a given ecoregional portfolio are highly important toward meeting the Conservancy's conservation goal for that ecoregion. However, the large number of conservation sites selected for a given portfolio precludes the possibility of any conservation organization or management agency of working at all of these sites simultaneously. Because of this paradox, some means of prioritizing portfolio sites for conservation action is needed.

In the CSP and NTP ecoregions, site priorities were based on 2 factors: (1) biological significance (i.e., the number of target occurrences selected to meet ecoregion conservation goals), and (2) the urgency of action required to abate threats. The biological significance component of the equation was developed with the assembly of the portfolio; however, information on which to determine site threat urgency required additional work. Ecoregional conservation team members and others knowledgeable about the respective portfolio sites were queried to identify threats to biodiversity occurring at each site and the magnitude of those threats. This information was assembled in order to assign a threat urgency rating for each portfolio site. Together, this information was used to place conservation sites into staging categories for future conservation action. Of the 71 sites in the CSP portfolio, for example, 16 require conservation action within 5 years, an additional 19 in 5-10 years, and the remaining 36 in 10-20 years (The Nature Conservancy Central Shortgrass Prairie Ecoregional Planning Team 1998).

Successful implementation of an ecoregional plan, however, will hinge on the ability of the Conservancy (and its partners) to develop strategies to abate existing and future threats to the biodiversity of the ecoregion. Depending on the circumstances, strategies for tackling these threats may be site-specific and addressed on a site-by-site basis, or may be more regional in scope and require implementation at broader levels. It will be critical, if the conservation goal is to be met, to operate successfully at multiple levels.

Strategies operating at multiple levels offer a potential for enhanced effectiveness in conserving the biological resources of an ecoregion beyond traditional site-based efforts alone. These strategies may be employed to tackle threats that are particularly difficult to address individually at specific conservation areas. Perhaps more frequent, however, they may be employed to offer some level of blanket protection to portfolio (in both high and low priority conservation areas) and non-portfolio areas alike. Because the scale of conservation work required to successfully implement ecoregional portfolios is daunting (perhaps too large for even the full array of conservation organizations and management agencies to undertake on a site-by-site basis), these multi-site strategies may be an efficient means of meeting the Conservancy's conservation goal for biodiversity protection in the ecoregion.

With this in mind, the Conservancy's ecoregional conservation teams are working with partners to develop action plans that will achieve the conservation goal of the long-term survival of the full array of species and natural communities occurring in the ecoregion. The tools for achieving this goal, by necessity, will be varied.

However, 1 thing is certain. Achieving the ecoregional conservation goal in any of the Plains ecoregions will necessitate the willing participation and support of all stakeholders. In a region where private lands sustain an overwhelmingly large proportion of its biodiversity (Ostlie et al. 1997), the most important of these will be the private landowners. Without their support, biodiversity conservation in the Great Plains cannot fully succeed.

ACKNOWLEDGMENTS

The authors would like to acknowledge the major contributions made to this paper by the Conservancy's ecoregional conservation teams in the Northern Tallgrass Prairie, Central Shortgrass Prairie, Northern Great Plains Steppe, Central Tallgrass Prairie, and Osage Plains/Flint Hills ecoregions. In addition, we would like to graciously thank Diane Vosick and Patrick Comer for their critical editing of this paper.

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PRIVATE PRAIRIE AND WOODLAND RESTORATION: UPDATING AN OLDER SUBDIVISION IN ILLINOIS

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Abstract: Hopewell Estates, platted on about 640 acres (259 ha) on the west bluff of the Illinois River, was begun in the 1970's. Most of the 420 lots sold, but only 124 residences are now in place. After the developer left, the residents organized as a village, Hopewell, Illinois, and built a new water company. Part of the subdivision (78 acres) was identified as an Illinois Natural Areas Inventory site in 1977. With the residences built on the bluff top, the wooded ravines and 14 hill prairies are still mostly intact but are being degraded by alien plant invasion and the lack of fire. We are restoring the native prairie and woodland on a number of lots we have purchased. Various low cost restoration and erosion control techniques are being used on these lots and on other parcels in Marshall County. These techniques include: 1) reducing alien plants and overstocked native trees to increase light for herbaceous plants, 2) log terracing with cut trees to reduce erowion on the steep slopes (up to 70%), and 3) controlled fire management. To sustain natural ecosystems on the landscape scale in Marshall County, both public and private restorations will be required, including small, private restorations.

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Key words: erosion control, Illinois Natural Areas Inventory, Illinois Nature Preserve, Illinois River, Marshall County

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About the same time Hopewell Estates Subdivision (Marshall County, Illinois) was being platted in 1977, the Illinois Natural Areas Inventory identified a 78-acre (32-ha) natural area in the middle of the subdivision that included 14 glacial drift hill prairies. The subdivision's forested lots on the west bluff of the Illinois River (about 20 mi north of Peoria) sold quickly. Then there were problems with the original water system, and then the developer left.

In 1983, the homeowners organized themselves into an incorporated village: Hopewell, Illinois. The homeowners then built a new water facility. Today (1998), there are still only 124 homes on 420 lots on about 640 acres (259 ha). With the residences built on the bluff top, the wooded ravines and 14 hill prairies are still mostly intact, but are being degraded by alien plant invasion and the lack of fire.

INTENSIVE RESTORATION

We purchased Lot 117 in September 1997 which turned out to be the center of the 3 Grade-A glacial drift hill prairies. About 0.7 acre (.28 ha) of the 1.2 acres (.49 ha) is hill prairie and the balance is oak savanna. In all of Illinois, the 1978 Natural Areas Inventory found only 14 acres (5.67 ha) of Grade-A glacial drift hill prairie.

Because of the high quality of the site, an intensive restoration was undertaken. About 22 days were spent clearing the woody shrubs and tree encroachment at the edges of the prairie. The woody plants removed were autumn olive (*Elaeagnus umbellata*), smooth sumac (*Rhus glabra*), gray dogwood (*Cornus racemosa*), white sassafras (*Sassafras albidum*), poison ivy (*Toxicodendron radicans*), riverbank grape (*Vitis riparia*), sow-teat blackberry (*Rubus allegheniensis*), and black raspberry (*Rubus occidentalis*). The overstocked savanna was thinned of sugar maple (*Acre saccharum*), eastern hop-hornbeam (*Ostrya virginiana*), wild black cherry (*Prunus serotina*), and some oaks (*Quercus* spp.). The woody plants were cut and the exposed cambium was treated with Roundup®.

In November 1997, with volunteer help, the prairie was burned for the first time in 30 years. (A long-term resident said the area used to burn every few years before the subdivision was platted). Preliminary dedication as an Illinois Nature Preserve was accepted in February 1998, and the final dedication of Hopewell Hill Prairies Nature Preserve was completed in May 1998.

In March 1998, the authors were able to purchase the adjacent lot (Lot 116) which included 0.3 acres (0.12 ha) of Grade-A prairie. Another 12 days of labor were spent in clearing woody vegetation from Lot 116 and the remaining part of the third hill prairie on Lot 117. Lot 116 will be offered as an addition to the nature preserve in October 1998.

In May of 1998, Tom Lerczak, the Illinois Nature Preserve Commission representative, secured an agreement for a natural heritage landmark status for the remaining 0.3 acres (0.12 ha) of Grade-A prairie on Lot 118 from the neighbor who resides there. Tom, Michelle Simone (Illinois DNR) and we put in another 5 man-days work to clear the woody vegetation on Lot 118. The plan is to burn this part of the prairie in fall 1998.

The restoration of the Grade-A hill prairie, about 1.3 acres (.50 ha) required about 39 days of labor. Thirty-five days were from the private owners and 4 days were assistance from agency employees. Most public agencies would not focus this many resources on such a small area. However, some interested individuals with volunteer restoration training and experience could provide the resources to complete this type of project.

PLANT RESPONSE

After the first burn in 30 years in fall 1997, and the wet spring of 1998, the plant response has been remarkable. The predominate early spring plants were hundreds of hairy puccoon (*Lithospermum carolinense*), prairie phlox (*Phlox pilosa*), and Seneca snakeroot (*Polygala senega*). The dwarf prairie willow (*Salix humilis*) bunches, which were top killed by the fire, sprouted profusely. We counted over 120 one-flowered cancerroot (a.k.a one-flowered broomrape) (*Orobanche uniflora*). The dominant early grass was Leiberg panicum (a.k.a prairie panicgrass) (*Panicum leibergii*) with much Pennsylvania sedge (*Carex pennsylvanica*) present.

Next in the season there were large numbers of pale echinacea (a.k.a. pale purple coneflower) (*Echinacea pallida*) blooming. The compass plant (*Silphium laciniatum*), prairie dock (*Silphium terebinthinaceum*) and wholeleaf rosinweed (*Silphium integrifolium*) with only a few blossoms in the previous year, bloomed profusely this year. The grasses present included side-oats gramma (*Bouteloua curtipendula*), prairie dropseed (*Sporobolus heterolepis*), little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*) and several panic grasses (*Panicum* spp.). The goldenrods (*Solidago* spp.) present were early (*S. juncea*), rigid (a.k.a. stiff) (*S. rigida*), gray (*S. nemoralis*), showy-wand (*S. speciosa*), Canada (a.k.a. tall) (*S. canadensis*), and elmleaf (*S. ulmifolia*). The asters (*Aster* spp.) included azure (*A. azureus*), white (a.k.a. heath) (*A. ericoides*), smooth blue (*A. laevis*), silky (*A. sericeus*) and aromatic (*A. oblongifolius*). Small numbers of green milkweed (*Asclepias viridiflora*), western sunflower (*Helianthus occidentalis*), button snakeroot (a.k.a. rattlesnake master) (*Eryngium yuccifolium*), gay feather (a.k.a. rough blazing star) (*Liatris aspera*), yellow stargrass (*Hypoxis hirsuta*), and downy gentian (*Gentiana puberulenta*) were also present.

Beside the encroaching woody shrubs mentioned previously, there is an abundance of leadplant (*Amorpha canescens*), and many New Jersey tea (*Ceanothus americanus*), American hazelnut (*Corylus americana*), and surrounding shadbush (*Amelanchier laevis*). The co-dominant trees in the surrounding savanna include dwarf chinquapin oak (*Quercus prinoides* var. *acuminata*), white oak (*Q. alba*), red oak (*Q. rubra*), black walnut (*Juglans nigra*), sugar maple, and various hickories (*Carya* sp.) A botanical study by Michael Jones is about to begin to determine the plant list. This study will be supported by the authors and the Illinois Wildlife Checkoff Fund.

MANAGEMENT PLANS

After the intensive restoration undertaken, only a small amount of annual maintenance time is anticipated. Annual or biennial burns are expected to control woody plant encroachment. Few troublesome weeds are present, although time will be needed to regularly monitor the occurrence of weeds. No garlic mustard (*Alliaria officinalis*) has been found yet and little yellow sweet clover (*Melilotus officinalis*), multiflora rose (*Rosa multiflora*), honeysuckle (*Lonicera* spp.), Canada bluegrass (*Poa compressa*), or Kentucky bluegrass (*Poa pratensis*) has been found in the prairie. Autumn olive seedlings from removed plants or neighbors' lots must be watched for and removed, or cut and treated. Limited amounts of seed may be collected to help restore the 2 Grade-B hill prairies in the natural area.

Some suggestions concerning intensive restorations are as follows:

1. Take out woody vegetation one layer at a time. We started with the autumn olive before seed-drop, then smooth sumac, then sassafras, and finally gray dogwood. By stump-treating in late summer, we were able to kill most of the clonal roots and have seen very little resprouting.

2. Mark trees 1 day, but cut them another day; this gives time for a second opinion. In the savanna border we counted the number of mature oaks and hickories. Then we left standing twice that number of 2- to 4-in dbh saplings, planning that half these would be lost before replacing the mature trees. We have already lost 3 mature red oaks by lightning strike, windstorm, and probably disease. The windfall crushed at least 1 replacement tree; however there is an overall beneficial effect of more light on the prairie.
3. Know your boundaries, we paid for a survey and have moved an encroaching decorative fence and some domesticated shrubs.
4. Know your plants. We have offered matching money to secure a Wildlife Checkoff Fund grant for a professional botanical inventory.
5. Place larger saplings and logs horizontally on steep slopes to reduce soil erosion.
6. Take some time every work session to enjoy the natural area.

FUTURE PROSPECTS

There are other vacant lots in Hopewell, Illinois, and other small parcels in Marshall County with high quality forest and savanna community plants. These areas are generally too small for conservation organizations to be interested in purchasing and maintaining; however, they are not too large for interested individuals to restore. We hope that Hopewell Hill Prairies Nature Preserve will provide a visual model for small restorations even in suburban settings.

As a residential development proceeds in Marshall County, the narrow band of forested river bluffs are at risk of being fragmented to the point of disrupting the natural processes of a woodland. To keep sustainable natural ecosystems in place on the landscape scale in Marshall County, both private and public restorations will be required, including small private restorations.

ROADSIDES AS PRAIRIE OPPORTUNITIES

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Abstract: Highway corridors total some 12 million acres of land in the United States. These corridors cross private and public lands where prairies exist or historically existed. What are we doing to preserve existing remnants as well as restore the miles of disturbed prairie? Case studies of individual state departments of transportation, as well as a large partnership will be described. The problems of seed source, availability and cost will be explored. This paper defines the remaining barricades to preservation and restoration of this large area of public land. It will also discuss how vegetation management, agency partnerships, and neighborly cooperation could help restore and preserve these often forgotten prairie pieces.

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Key words: highway rights-of-way, prairie remnants, state departments of transportation, vegetation management.

THE CLEAR ZONE

Highway rights-of-way or roadsides serve many purposes. They accommodate errant vehicles, signage, and maintenance equipment. At the same time the vegetation on roadsides serves as erosion control of slopes, water quality filters, wildlife habitat, and an aesthetic view for highway travelers. I suggest that all purposes can be met by the restoration or preservation of grasslands on roadsides.

The clear zone is the roadside border area, starting at the edge of the traveled way, that is available for corrective action by errant vehicles (1991 AASHTO Guide for Transportation Landscape and Environmental Design). The designed width of the accident recovery area is determined by the speed limit. No objects including trees of more than a 4–in diameter are allowed within this zone. As a result, the clear zone (not the entire right-of-way) of a roadside must be maintained as grasslands that can be mowed to prevent encroachment of potentially hazardous trees and shrubs. It has become common practice to keep these zones mowed continually. The consequences include: high maintenance costs, mower/vehicle accidents, monocultures of grasses, and a front lawn expectation from the traveling public.

Beyond the city limits, that expectation does not relate to the adjacent landscape. Rural recovery areas can be safe as well as interesting, diverse, and require less maintenance if native grasslands are used and/or preserved. Incidental consequences include: regionally recognizable vegetation, seasonally dynamic landscape, small mammal and song bird habitat, deep-rooted erosion control, water quality improvement, and preservation of our natural heritage. If highway users understand this unmowed grassland and its environmental ramifications, they are likely to be supportive. That has been the experience of states such as Iowa, Wisconsin, Illinois, Minnesota, Kansas, Missouri, Oklahoma, Texas, Utah, Oregon, California, and even Florida. Using native forbs and grasses in clear zones is good common sense. All states have some native grassland community. Not all are prairie. I have walked on meadows in Maryland, balds in North Carolina, desert grasslands in Arizona, shortgrass prairie in South Dakota, and valley grasslands in California. Within each state, various natural regions exist. Texas, for example, has 26 natural regions. You can understand why 1 grass seed mix might not be successful in all 26 regions. Yet state departments of transportation (DOTs) have traditionally used standard mixes, a kind of 1-size-fits-all approach. They have found mixes, most using nonnative species, that tolerate a wide range of harsh environmental conditions. Most highway projects leave behind disturbed soils, on steep slopes, open to new weed seeds, exposed to desiccating sun and winds. These soils are not kind environments for seed germination. The idea of matching these conditions with appropriate native grasses and forbs would mean site-specific seed mixes.

OBSTACLES

This more ecological approach is doable, but at what price? The cost of native forb and grass seed is notably higher than that of traditional mixes. However, with the native seed, seeding rates are much lower, plus reseeding is rarely needed, thus lowering the cost. Of course availability of native seed for these projects continues to be sparse. Seed growers are emerging to address the need. But what if the DOT or other consumers specify regional or local ecotypes? This question worries many seed growers, yet provides a market niche for other growers. Native grasses and forbs take too long to establish; DOTs want quick cover. To meet erosion control standards, this is true. We are finding a number of cool season native grasses such as Canada wild rye (*Elymus canadensis*), and also some early succession forbs that can be a part of the mix to get those necessary early results. The perennials can use them as cover.

But why can we not just do it the way we have always done it? This common question is met with some new realities. Many of the plant species we have used as quick cover in landscaping, erosion control, mitigation, and revegetation are showing up on state noxious weeds lists. We have some responsibility not to plant invasive species: reed canarygrass (*Phalaris arundinacea*), sweet clover (*Melilotus* spp.), crown vetch (*Coronilla varia*), bird's-foot trefoil (*Lotus corniculatus*), Bermudagrass (*Cynodon dactylon*), smooth brome (*Bromus inermis*), and the list goes on.

These purposefully planted nonnatives do not respect political boundaries and soon cross to adjacent lands. The eastern forested states question the use of native forbs and grasses because of continual encroachment by woody species. It has been shown by old field succession research in New Jersey, that working with natural succession, reduced mowing could be the answer to diverse roadsides.

Mowing once every 3-5 years could be frequent enough to discourage woody invasion. This would keep the clear zone safe at minimal maintenance cost. Does not the public expect mowed turf? The public will think we are not doing our job if they see a bunch of weeds. Has anyone asked the public lately? The idea of our roadsides as our nation's front lawn was born in the 1930's when roadside development began. In light of new environmental and economic understanding, the traveling public is likely to accept a new aesthetic on roadsides, specifically rural roadsides. By increasing public awareness through the media and signage, this obstacle can be overcome.

STATE DOTs

These obstacles combined with harsh roadside environments have prevented half the states from experimenting with this grassland solution. Here are some state DOTs who are having success.

Wisconsin and Minnesota have reduced rural mowing laws, not just policies, that require the mowing of only an 8-ft wide strip for safety purposes. Only during the month of September can they mow the entire right-of-way. Rural rights-of-way therefore do not have a front lawn look. Illinois and Iowa are planting nearly 1000 acres of prairie grasses annually. These historically prairie states are restoring their natural heritage.

A group of 6 states have combined experience to plan and restore a Prairie Passage from border to border. This unique partnership includes: Texas, Oklahoma, Kansas, Missouri, Iowa, and Minnesota. Improved public awareness about prairie protection and restoration should be the result.

Utah is combining its interest in nonnative species control with its interest in native species restoration within a statewide GIS system. They are the first to use global positioning units, and existing land information to combine data for vegetation management purposes.

The California Department of Transportation (Caltrans) follows some Midwest efforts in identifying native plant community remnants and protecting them. Although rights-of-way, by their very history of disturbance, are not likely to contain quality remnants; highways that were built years ago in areas with little human disturbance often were invaded by adjacent seed source and native seed banked in the soil. These remnants are sometimes all the natural heritage record we have in highly developed areas. Caltrans has found 11 and is writing specific management plans for each. They have signed the sites and used them for public awareness efforts. They intend to designate 19 more shortly.

As far as we have come in the use of native grasses and native forbs on roadsides, our best results are likely to come from our protection of similar remnants. The initial cost will be less. The maintenance can be reduced. Diversity and habitat quality will be higher. This opportunity could be more easily accepted by roadside managers. We need to locate those remnants that remain and manage them differently.

THE INVASIVE SPECIES SIDE OF RESTORATION

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Abstract: At this time we daily lose 4500 new acres to nonnative invasive species. We are losing diversity, natural heritage, and wildlife habitat. What else are we losing and what are we doing about it? This paper explains the development of a national nonnative invasive species strategy. This strategy addresses: 1) prevention, 2) control, and 3) restoration as the logical follow-up to the invasive species problem. I will explore the policies and politics involved, as well as underscore the usefulness of the strategy to the audience. I will offer some of the available policy tools to help address these weed invasions.

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Key words: nonnative plant species, politics, weed invasions.

We cannot be involved with restoration or preservation of native plant communities without being involved with nonnative invasive plant species. Call them exotic, pest, alien, noxious, introduced, naturalized or escaped plants; the bottom line is that they compromise the quality of plant communities by reducing diversity, displacing endangered species, degrading natural heritage remnants, and diminishing wildlife habitat.

Economic and Ecologic Losses Rise

However, as we continue to lose 4500 new acres daily to the invasion of nonnative species, we must recognize all the costs. In addition to the losses to the environment, there are great losses to the economy. Invasive plants are costing millions in research. The cost to farmers and ranchers has put some out of business. The resale value of infested properties goes down. Control costs on public lands alone take too many of taxpayers' dollars. The loss of recreational value to our lakes and rivers is rising. Reduced hunting and fishing revenues add into that loss. These economic impacts are being noticed especially by congressmen in the west, in Hawaii, and in Florida. In April 1998, the Federal Interagency Committee on the Management of Noxious and Exotic Weeds (FICMNEW) gave a congressional briefing to increase their understanding of the environmental and economic costs of invasive species across the country. Although the ecological arguments for weed control have been forwarded since the 1970's, it is likely that these economic arguments will result in national action.

THE NATIONAL STRATEGY

Background

At that congressional briefing, a national strategy for invasive plant management was explained. This strategy was 4 years in the making and is the result of a federal interagency meeting held in 1993. The 1990's was soon to become the era of weed summits and task forces discussing harmful nonindigenous or nonnative invasive species, biotic invasives, or invasive exotics. The 1991 Biological Pollution Symposium in Indiana attracted 300 people from 35 States to address weed issues. As weed activists became more political, Congress requested a study of weeds by the Office of Technical Assessment (OTA). The 1993 OTA report underscored the need for national policy, better environmental education, and adequate funding to limit invasives. That 1993 Federal interagency meeting led to a Memorandum of Understanding signed by 16 agencies forming a permanent committee known as FICMNEW.

Restoration, 1 of 3 National Goals

FICMNEW arranged for 3 weed summits (Denver, Fort Lauderdale, and Albuquerque). Their purpose was to develop that national policy called for by Congress. In that effort, FICMNEW also appealed to the private sector to join in a partnership against weeds. The vision was soon articulated in "Pulling Together, National Strategy for Invasive Plant Management." The strategy's 3 national goals included:

1. Effective prevention
2. Effective control.
3. Effective restoration.

Restoration is key to making this all work. The use of native plants is specified for restoration. The strategy was recently reprinted with more than 125 endorsements from both public and private sectors. A strong partnership has emerged. During the fall 1997, members of FICMNEW were summoned by Vice President Gore's office to a Nonnative Invasive Species Task Force. A letter about that issue had arrived from Don Schmitz, the Florida Department of Environmental Protection. Five hundred scientists had added their signatures to the letter. The task force has written Executive Order (EO) 11032, to be signed by President Clinton during the summer of 1998. The Executive Order will have the weight of law. It will set into motion a requirement for vegetation management planning, monitoring, implementation and restoration.

Although EO 11987 directed at the control of exotic organisms was signed by President Jimmy Carter 20 years ago, this EO is expected to result in more action because of the current ecologic and economic impacts. In spring 1998, members of the interagency committee held a Congressional Briefing to address weed issues and roll out 1 of their educational efforts, a weed fact book. The turnout was strong. Support from congressional delegations from Western States, Hawaii, and Florida particularly, show an understanding of the many impacts of nonnative invasive species. With interagency, public and private sector, plus Congressional partnerships increasing, we should be able to reverse the trend of economic and ecologic losses. Restoration will be part of the answer.

FAUNA OVERWINTERING IN OR ON STEMS OF WISCONSIN PRAIRIE FORBS

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Abstract: This is a report of on-going research into the fauna overwintering in or on stems of Wisconsin prairie forbs. Two of 20 plant species studied to date produced no fauna, but the 18 others produced 9 to 31 taxa. The average among these 20 plant species was 15 arthropod taxa. The discovery of this diverse stem-fauna, comprised of herbivores, detritivores, predators and parasitoids, of immatures as well as adults, prompts reconsideration of how prairies are currently managed for biodiversity. Management implications are discussed.

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Key words: arthropod taxa, biodiversity, detritivores, herbivores, parasitoids, predators.

For many years, conservationists have urged us to leave dead wood in our woodlands because a diversity of wildlife uses it. Invertebrates comprise the vast majority of this wildlife. An analogous situation exists in prairie: many invertebrates live over the winter in or on the dead stems of prairie plants. The following is a preliminary report of an on-going study of this fauna.

The discovery of this diverse stem-fauna, comprised of herbivores, detritivores, predators and parasitoids, of immatures as well as adults, prompts reconsideration of how prairies are currently managed for biodiversity.

MATERIALS AND METHODS

All plant specimens were collected at Thomas Wet Prairie, owned by The Prairie Enthusiasts - Southwest Chapter, in Grant County, Wisconsin. This site has a history of grazing and has been partially burned twice in the last decade, over which period it has not been grazed. Abutting land is still pastured. Herbaceous wetlands, low pastures, row crops, overgrown oak savanna and oak woods, and overgrazed, limy hill prairies characterize this hilly agrarian landscape.

Prairie plant species with larger diameter stems were chosen, and stems with galls were preferentially collected. In late September, stems of each species were placed into their own sterile container over freshly sterilized soil. Stems were cut into lengths approximating the width of the container and were jumbled together loosely to allow animals to extricate themselves from the stems and to move about freely and, with luck, toward the light and so into the trap. The containers were tall kitchen trash cans with slits cut in their bottoms for drainage.

Queen-sized panty hose was stretched over the open top of each container to keep fauna from entering or exiting, and these were left outdoors on a second story, open porch over the winter.

The containers were brought indoors and tightly caged in March, sheathed in black plastic bags and provided with a zippered plastic bag over a clear plastic collar. The black plastic bags were lawn and leaf bags, the zippered plastic bags were the 1-gallon size (zippers on larger bags quickly deteriorate), and the clear plastic collars were the tubular midsection of 2-L soda bottles. Both clear plastic packing tape and fiber reinforced packing tape were used to hold these components together and to effect a complete seal of the bagged container.

The clear plastic collar was taped into 1 corner of the top of the container, angling outward. The container was set into a black plastic bag that was drawn up and tightly taped around the container just below its lip, to deter animals from wandering down between the black bag and the container. The black bag was then drawn across the container's open top. This involved cutting away part of the bag and using packing tape to seal the cut edges together. The black plastic was funneled into the clear plastic collar, cut off and taped to the collar, leaving as much of the collar free of this black plastic as possible.

The top of the container was then covered with supplemental layers of black plastic to further occlude light, so that the only light entering the container was that entering at the clear plastic collar. A zippered plastic bag was taped to the distal end of the collar and positioned so the collar penetrated the base of the zippered bag and so the zippered end was farthest from the container. One's sole access to the fauna was through the zippered bag.

Containers were placed on lab tables so their zippered bags were at about face-height to facilitate checking for animals. By reaching into the container through the plastic collar, some stems were piled up and spilled over into the plastic collar to facilitate movement of wingless animals into the zippered bag.

Excessive condensation inside the zippered bags was a problem with this design, though high humidity in the containers is desirable. The containers were checked and any condensation in the zippered plastic bags or in the clear plastic collars was removed with paper towels 2 or 3 times daily. Paper towels were reused but each container had its own supply of paper towels so that accidental introduction of fauna originating in one container to a second container could not occur. A blank sheet of white paper held up behind the zippered bag as one peered through it made the tiny animals easier to see.

After about a week of apparent inactivity, small animals began to appear in the zippered plastic bags. These were caught, usually with an aspirator, the animals killed in 80% EtOH, and sorted under a microscope into vials containing 80% EtOH. The aspirator was cleaned after each use, so that accidental introduction of fauna originating in one container to a second container could not occur.

The name and number of the plant were marked on tape on the outside of the container, on the zippered bag, and also on an aluminized paper tag that was tied to one of the topmost stems inside the container: e.g. swamp lousewort 4701. As different animals appeared in that container, they were given numbers (4701.1, 4701.2, etc.) and stored in vials in a rack. Having all the vials for swamp lousewort together made it easy to slip that plant's vials under the microscope to see if newly caught animals were something new. When more individuals of animal 4701.2 appeared over ensuing days, these were simply added to the same vial in the rack. As time passed, there were more and more vials in the rack. Some larger animals were killed in a killing jar, point-mounted, and provided with numbered tags on their pins.

The containers were maintained until the eruption of fauna subsided or the arrival of new taxa slowed to a standstill. This was 50 days in spring 1997, but it was 88 days in spring 1998. These data were put into a database with my other prairie insect data, and the specimens themselves were deposited in the Insect Research Collection at University of Wisconsin—Madison.

At the end of this process, the animals of each sort were counted, with 2 exceptions. Flies and fly larvae (Diptera) and springtails (Collembola) were often common and no effort to collect them all was made.

RESULTS

To date, 20 species of prairie forbs have been studied. Two of these species produced no fauna, but the 18 others produced between 9 and 31 taxa (Table 1). The average among these 20 plant species was 15.5 arthropod taxa.

A list of the taxa produced with the number of each taxon that appeared is provided for 5 plant species: spotted joe-pye-weed (Table 2), gayfeather (Table 3), green-eyed susan (Table 4), swamp lousewort (Table 5) and bottle gentian (Table 6).

As more specimens are identified in the future, these lists will probably change, and the total numbers of taxa for a plant may go up or down a bit as a result. The scale of diversity will not change, however, and this is the factor that these tabular results show.

These taxa include animals that overwintered as eggs or early instars, emerging into the light traps as immatures, and others that overwintered as larvae, pupae or adults, emerging as adults. These include herbivores, detritivores, predators and many different parasitoids, tiny wasps that develop within the bodies of other insects. Some of these taxa will never be identified to species, but with the help of experts, I expect to identify them to family and perhaps to genus. Some may be new to science. Most of these animals are tiny in contrast to the charismatic megafauna that get the bulk of conservationists attention: "gigantic" animals such as the Karner blue butterfly.

It is possible that some of these animals might have left the stems and overwintered in the sterile soil provided in each container. However, I think that would be true for only a few of these taxa, based on what is known of the life histories of these animals, many of which are wasps and beetles. The soil serves primarily as a sponge to maintain humid conditions inside the container.

DISCUSSION

The technique used here reveals only those fauna that use a particular part of these particular plants, growing on a single site. Furthermore, the use is only at a particular time of year. Surely the stem-fauna differs over the growing season, among yet other plants, and from place to place. And surely many other animals use these few plants in other ways.

Table 1: Plant species studied and the number of arthropod species produced from the stems of each, in ascending order of biodiversity.

Common Name	Plant Species	Arthropods
swamp milkweed	*Asclepias incarnata*	0
blue vervain	*Verbena hastata*	0
sawtooth sunflower	*Helianthus grosseserratus*	9
great St. John's-wort	*Hypericum pyramidatum*	10
late goldenrod	*Solidago gigantea*	10
tuberous sunflower	*Helianthus tuberosus*	12
smooth ironweed	*Vernonia fasciculata*	13
New England aster	*Aster novae-angliae*	14
white wild indigo	*Baptisia lactea*	14
ox-eye	*Heliopsis helianthoides*	16
spotted joe-pye-weed	*Eupatorium maculatum*	17
boneset	*Eupatorium perfoliatum*	17
swamp lousewort	*Pedicularis lanceolata*	18
Culver's-root	*Veronicastrum virginicum*	18
gayfeather	*Liatris pycnostachya*	20
Canada goldenrod	*Solidago canadensis*	20
bottle gentian	*Gentiana andrewsii*	21
cup plant	*Silphium perfoliatum*	23
common sneezeweed	*Helenium autumnale*	27
green-eyed susan	*Rudbeckia laciniata*	31

Table 2: These are the 17 taxa produced by spotted joe-pye-weed 3638, in the order in their appearance.

Species #	Order	Family	Name	Arthropods
3638.1	Diptera	Sciaridae		4
3638.2	Hymenoptera	Pteromalidae	*Habrocytus* sp.	2
3638.3	Diptera	Agromyzidae	*Melanagromyza* sp.	10
3638.4	Hymenoptera	Braconidae	*Bracon palliventris*	4
3638.5	Hymenoptera	Ormyridae	*Ormyrus* sp.	2
3638.6	Coleoptera	Cleridae	*Enoclerus rosmarus*	1
3638.7	Diptera		(larvae)	many
3638.8	Acari			many
3638.9	Coleoptera	Languriidae	*Acropteroxys gracilis*	7
3638.11	Hymenoptera			1
3638.12	Coleoptera	Mordellidae		4
3638.13	Coleoptera	Cerambycidae	*Dectes sayi*	1
3638.14	Hymenoptera	Braconidae	*Schizoprymnus* sp.	3
3638.15	Diptera	Cecidomyiidae		2
3638.16	Hymenoptera			13
3638.17	Acari			4
3638.18	Hymenoptera	Braconidae	*Chorebus* sp.	3

Table 3. These are the 20 taxa produced by gayfeather 4685, in the order of their appearance.

Species #	Order	Family	Name	Arthropods
4685.1	Hemiptera	Membracidae	(nymphs)	13
4685.2	Hemiptera	Miridae	(nymphs)	5
4685.3	Acari			many
4685.4	Orthoptera	Tettigoniidae	(nymphs)	5
4685.5	Coleoptera	Cleridae	*Enoclerus rosmarus*	2
4685.6	Diptera	Cecidomyiidae		2
4685.7	Orthoptera	Gryllidae	*Oecanthus* sp. (nymphs)	31
4685.8	Diptera		(larvae)	many
4685.9	Hymenoptera			3
4685.11	Hymenoptera			4
4685.12	Collembola	Sminthuridae		2
4685.13	Collembola	Sminthuridae		many
4685.14	Diptera	Cecidomyiidae	*Heteropeza pygmaea*	many
4685.15	Acari			few
4685.16	Acari			few
4685.17	Acari			few
4685.18	Diptera	Cecidomyiidae		1
4685.19	Collembola	Hypogastruridae		few
4685.21	Hymenoptera			2
4685.22	Diptera	Mycetophilidae	*Leia bivittata*	1

Table 4. These are the 31 taxa produced by green-eyed susan 4696, in the order of their appearance.

Species #	Order	Family	Name	Arthropods
4696.1	Hymenoptera			3
4696.2	Hymenoptera	Braconidae	*Heterospilus* sp.	2
4696.3	Hymenoptera	Braconidae	*Heterospilus* sp.	1
4696.4	Hymenoptera			9
4696.5	Hymenoptera	Braconidae	*Nealionus curculionis*	6
4696.6	Araneae			1
4696.7	Hymenoptera			2
4696.8	Hymenoptera			10
4696.9	Hymenoptera	Braconidae	*Heterospilus* sp.	1
4696.11	Coleoptera	Curculionidae		5
4696.12	Coleoptera	Cleridae	*Enoclerus rosmarus*	1
4696.13	Acari			few
4696.14	Diptera	Cecidomyiidae	(larvae)	some
4696.15	Coleoptera	Mordellidae		6
4696.16	Diptera	Cecidomyiidae		1
4696.17	Hymenoptera	Eurytomidae		1
4696.18	Hymenoptera			2
4696.19	Hymenoptera			1
4696.21	Hymenoptera			1
4696.22	Coleoptera	Staphylinidae		1
4696.23	Orthoptera	Gryllidae	*Oecanthus* sp. (nymphs)	58
4696.24	Acari			few
4696.25	Hymenoptera			1
4696.26	Diptera		(larva)	1
4696.27	Hymenoptera	Ichneumonidae	*Trathala granulata*	2
4696.28	Hymenoptera	Braconidae	*Chorebus* sp.	2
4696.29	Diptera	Agromyzidae	*Melanagromyza* sp.	3
4696.31	Collembola	Sminthuridae		1
4696.32	Acari			1
4696.33	Diptera			1
4696.34	Hymenoptera	Braconidae	*Schizoprymnus* sp.	4

Table 5: These are the 18 taxa produced by swamp lousewort 4701, in the order of their appearance.

Species #	Order	Family	Name	Arthropods
4701.1	Hymenoptera	Eurytomidae		21
4701.2	Hymenoptera	Braconidae	*Bracon palliventris*	23
4701.3	Hymenoptera	Eupelmidae	*Macroneura vesicularis*	5
4701.4	Hymenoptera	Braconidae	*Chorebus* sp.	36
4701.5	Diptera			2
4701.6	Hymenoptera			4
4701.7	Coleoptera	Cleridae	*Enoclerus rosmarus*	2
4701.8	Hymenoptera			24
4701.9	Acari			some
4701.11	Hymenoptera			82
4701.12	Diptera			9
4701.13	Hymenoptera			2
4701.14	Orthoptera	Gryllidae	*Oecanthus* sp. (nymphs)	18
4701.15	Hymenoptera			1
4701.16	Diptera	Cecidomyiidae		2
4701.17	Acari			some
4701.18	Hymenoptera			2
4701.19	Diptera	Cecidomyiidae	*Heteropeza pygmaea*	14

Table 6: These are the 21 taxa produced by bottle gentian 4705, in the order of their appearance.

Species #	Order	Family	Name	Arthropods
4705.1	Diptera	Agromyzidae	*Melanagromyza* sp.	12
4705.2	Hymenoptera	Braconidae	*Bracon palliventris*	47
4705.3	Hymenoptera	Braconidae	*Heterospilus* sp.	7
4705.4	Hymenoptera	Braconidae	*Heterospilus* sp.	6
4705.5	Hymenoptera	Pteromalidae	*Habrocytus* sp.	3
4705.6	Hymenoptera	Eupelmidae	*Macroneura vesicularis*	4
4705.7	Hymenoptera			5
4705.8	Coleoptera	Mordellidae		75
4705.9	Hymenoptera	Braconidae	*Schizoprymnus* sp.	19
4705.11	Lepidoptera			1
4705.12	Hymenoptera			219
4705.13	Hymenoptera			3
4705.14	Acari			some
4705.15	Diptera	Cecidomyiidae	(larvae)	many
4705.16	Hymenoptera			28
4705.17	Diptera	Cecidomyiidae	*Heteropeza pygmaea*	many
4705.18	Acari			some
4705.19	Coleoptera	Mordellidae		1
4701.21	Collembola	Sminthuridae		many
4701.22	Diptera	Phoridae		1
4701.23	Diptera	Sciaridae		40

This novel technique shows that a great diversity of fauna live inside or attached to the outside of herbaceous plant stems over the winter. It also shows that different life stages overwinter on plant stems. These taxa include an array of parasitoids as well as herbivores, detritivores and predators lower on the trophic pyramid. Many parasitoids are very specific in their use of hosts. Thus, we can assume that some of the animals I reared out use particular species among those that have appeared as adults in my containers. Some of these parasitoids probably parasitize other parasitoids in these samples. Some of the herbivores are very choosy about the food plant in which they develop. These first experiments have given but a glimpse of what occurs in or on the stems of various prairie plants.

A frequent prairie management technique is the burning of prairies (or preferably the burning of parts of each prairie) in fall, winter, or spring—just the period over which these taxa are living in or on the stems that would probably be consumed or overheated by the fire. A less frequent prairie management technique is mowing in the fall, winter, or spring, when the flora is inactive, but when these animals may be vulnerable. Many prairies are grazed so hard that much of this stem-fauna may be extirpated through eradication of some plant species from the pasture or through suppression of some plants to the extent that stem development is inadequate to support some of these fauna. Mowing or haying during the summer can have these same effects.

Vigorous application of any of the tools of prairie management must be detrimental to some fauna, probably especially so to those parasitoids that depend on certain herbivores that, in turn, depend on certain plants. These most highly specialized fauna are at risk of eradication from prairie remnants as a result of our management practices, yet most prairie managers have essentially no knowledge of these animals. Indeed, many entomologists have essentially no knowledge of these fauna. That is the state of our common knowledge, given the economic orientation that pervades professional entomology.

Because we know so little about the invertebrate fauna native to our prairies, it seems wise to hedge our bets in the course of designing and implementing management activities so that we lessen the risk of eradicating the very fauna that define a site as native grassland: the specialist fauna that depend on particular plants and/or animals found in that habitat.

In responsible and effective land management, one should consider what is known: in this case, we know at least something about how many prairie plants respond to fire, grazing or mowing. But one must also consider what is not known: in this case, we know almost nothing about what specialist fauna are present and how our management activities affect their populations. Prudence requires that we moderate our management activities accordingly.

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POLLINATORS AND PRAIRIE RESTORATION[1]

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Abstract: Due to the activities of man on the North American plain, there is a loss of habitat and subsequent loss of many feral species of native insects, which rely on blooming plants to complete their life cycle. This paper will outline some of these relationships, especially as it pertains to non-*Apis* bees such as *Bombus* species and native leafcutter bees. As conservationists, we have to remember that the ecosystems we are trying to rebuild should include species that flower through the earliest parts of spring to the first frost of autumn. These plant species not only feed pollinating insects, but the song birds and mammals that in turn prey upon these bees, dipterans (flies) and formica (ants) species which rely on season-long food from the nectar and pollen of flowers. Bats, mice, voles, moths, butterflies, beetles and humming birds also use these flowers for a food supply. Native prairie legumes have a large role to play in preserving these forgotten pollinators that in many regions are either extirpated or are in unsustainably low numbers. Native legumes also have a role to play in generating organic matter from fixing atmospheric nitrogen and bringing up leached nutrients from lower soil strata with their deep roots. In highly saline soils, this deep root penetration will assist in lowering the water table so that salts will not make their way to the surface. It has been noted that earthworm populations do increase more rapidly with legumes and are at a greater density over time compared to a pure grass stand.

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Key words: *Bombus*, leafcutter bees, legumes, native insects, non-*Apis* bees.

You owe 1 out of every 3 bites you eat to bees or other pollinators. Pollination is a fundamental ecological service, critical to the stability of world food supply and 90% of the world's flowering plants.

As scientists, interested lay people and professional reclamation folk, we have a responsibility to do the best job possible given our resources and time. I believe we are not doing a good job when it comes to planting the species that are best suited to preserving native pollinators. According to the USDA, we are facing an "impending pollinator crisis," which has already begun in the Western U. S. and will worsen before it can be resolved.

Pollination is essential to our livelihood, a crucial factor in successful commercial orchard and other crop production, endangered species protection, urban gardening, ecological restoration, and the dairy and beef industries. The relationships between plants and their pollinators form critical links in the structure and function of agricultural and wild land communities. Habitat loss, disease, and pesticides are taking a serious toll on these relationships, many of which are products of thousands of years of natural and cultural selection.

In an era when human activities place increasing pressure on both natural and rural landscapes, it is no longer possible to ignore the vital role of pollination services or the frequently negative impacts that we are having on plant/pollinator relationships. Wild pollinators play an indispensable role in agriculture and wild lands. And yet they are all too often neglected in plans for ecological restoration, pesticide control, and in other land management decisions. We have yet to establish sufficient understanding and investment to support biodiversity and stable economic populations of wild pollinators. In the U. S., there already have been many large crop failures or poor harvests due to pollinator shortages. In California, the 1996 almond crop; in Maine, the blueberry crop; and throughout the last several years in New York state the pumpkin crop. Pollinators need protection from pesticides. In Canada during the mid-1970's, coniferous forest pests reduced native bee populations to the extent that blueberry yields were reduced for a period of 4 years. Pesticides used in agriculture are toxic to pollinating insects, but only honeybee colonies can be easily moved away from the area.

In our own province of Manitoba, Canada, there are many regions without economic numbers of pollinators—tame or wild. These are my own observations, as I have managed a commercial apiary

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[1] This paper is a summary from "The Forgotten Pollinators" 1997 Conference. Our company, International Pollination Systems Inc., has one of the conference partners, Dr. Ron Bitner, sitting on our board.

in Manitoba for almost 20 years. Honeybee operations have been bankrupted due to low honey prices, mite problems and pesticide pressure. In areas that have no honeybees, farmers cannot grow cross-pollinated crops such as buckwheat, borage, bird's-foot trefoil, and spice crops. We have lost our grain export subsidies in Canada, making the economics of growing of these niche crops all the more important over the traditional cereals for growers. Due to the lack of diversity in botanical agriculture areas, economic populations of wild pollinators are not present. Loss of nesting habitat has become a large culprit, due to farmers cultivating the prairie landscape "fencepost to fencepost."

Pollination Basics

Technically speaking, pollination is the transfer of (male) pollen grains to the (female) stigmatic organs or ovaries in flowers. A fertilized flower will, in most cases, produce full-bodied fruit containing a full set of fertile seeds capable of regeneration. If a flower is not fertilized, it may abort or wither away without producing fruit. A flower only partially fertilized will result in misshapen fruit with few or no seeds. The size of a "fruit" is often increased by pollination. It has been estimated that the size of cotton, for example, would increase by 10-20% if it were fertilized, an uncommon occurrence since the crop is typically dosed heavily with pesticides (Nabhan et al. 1996).

Countless bees, wasps, thrips, moths, butterflies, flies and beetles, and a considerable number of vertebrates serve as pollinators. Hummingbirds are the best known vertebrate pollinators, but perching birds, flying foxes (large bats), fruit bats, opossums and lemurs are vertebrates that have been known to pollinate.

The honeybee is not the only domesticated species of a hymenopteran insect: alfalfa leafcutter bees (*Megachile* spp.), alkali bees, bumblebees (*Bombus* spp.) and orchard bees are all available commercially. In western Canada and the Pacific northwest, the alfalfa leafcutter bee does a yeoman's service pollinating the alfalfa seed crop as well as niche crops like hybrid canola seed and vegetable seed. The docile bumblebee does a remarkably efficient pollinating job on most flowering crops, but due to their high cost, they are usually regulated to greenhouse crops such as tomatoes and cucumbers. Alkali bees and orchard bees, though available commercially, are not used to any great extent when compared to the other domesticated pollinators.

Purists in the native reclamation business may insist on only using local insects for pollination. To my professional knowledge, feral species are not available. Perhaps down the road this is a venture worth considering. Much work has been done with feral bumblebees all over North America (Bitner personal communication). But success has been quite limited; the commercial bumblebee ventures do not use feral species.

Arguments have been made that by overwhelming local pollinators in areas where one uses domestic pollinators, that native bees populations are suppressed. I do not believe that there have been any studies done regarding this, although I know that on our farm we have an abundance of wasp and hornet's nests in and around our sheds, and granaries. Common sense tells us that floral diversity begets pollinator diversity.

What our Industry Can Do

When planning your plant species for your site, there are several things to consider:

1. **What species is nectar producing, and at what time do they flower?** Pollinating insects, especially solitary bees such as bumblebees, are often on the verge of starvation. This is due to the fact that they do not store nectar or honey in appreciable amount like a honeybee colony. Heinrich (1979) noted that even the hardy bumblebee colony is only 1 step from collapse due to starvation. He described life in the bumblebee colony as a precarious one. As the cólony grows there has to be a nectar supply available throughout the entire spring, and competition for that resource from other species of insect pollinators such as honeybees cannot be too great either.

2. **To ensure that wild pollinators thrive, there has to be a succession of sequential flowering of a diversity of plants.** One could plant willows (*Salix* spp.) in riparian areas, vetches (*Astragalus* spp.) and field mint (*Menthah arevensis*) in mesic areas for the spring. For the summer period, purple prairie clover (*Petalostemum purpureum*) and American vetch (*Vicia americana*) in mesic areas with wild bergamot (*Monarda fistulosa*) in damper locales. In the fall there are the goldenrod (*Solidago* spp.) and asters (*Aster* spp.).

3. **There has to be floral diversity to obtain pollinator diversity**. Many pollinators such as bumblebees and hummingbirds rely on flowers with a deep stigma. Generalist, such as wild leafcutter bees, can do a fine job on shallow-flowered species. Different species flower at different times of the day, and likewise pollinators occupy different niches in their natural habitats. Many pollinators, such as Monarch butterflies (*Danaus plexippus*), migrate long distances and need wild areas with suitable nectar sources to complete their season-long journey. Habitat fragmentation is a real problem, because these species can only fly so far between meals. One solution to this problem is for the "highways" people to vegetate roadsides with suitable species. This would be a "pollinator corridor" in the same fashion that other wildlife corridors operate. That is, habitat being kept intact so that wildlife can routinely migrate from area to area.

4. **Plants and pollinators both need protected habitat**. A good example is the last remaining natural population of a rare evening primrose that lives in California's Anticoch Dunes National Wildlife Refuge. Though the primrose is protected, its hawkmoth pollinator has not reappeared after years of pesticide spraying in nearby vineyards, and reproduction has remained low (Nabhan et al. 1996). The future of this plant remains in jeopardy as it produces few fruits and low percentages of viable seeds, while its weedy neighbors produce many. In Iowa, where only 200 acres of unplowed "virgin" prairie remains intact, prairie wildflowers now suffer low seed yields for lack of adequate visitation rates by pollinators (Heinrich 1979).

I realize that there is not a bountiful supply of suitable native flower seeds, but we as an industry have to start asking why we are doing this work. When I see reclaimed prairie without flowers, I see lost opportunities: for the honey industry, for local farmers and gardeners, and for our natural heritage. We lose rare and beautiful butterflies and our colorful hummingbirds.

The future of our farms depends upon pollination. Pollination is a necessary step in the production of nearly all the fruits and seeds we eat, and in forage crops for livestock. Growers of apples, almonds, cherries, blueberries, pumpkins, cranberries, alfalfa and many other crops depend on insect pollinators, both managed and wild, in order to produce fertile seeds and full-bodied fruit.

Recent surveys document that more than 30 genera of pollinators including hundreds of species, are required to pollinate the 100 or so crops that feed the world (Nabhan et al. 1996). Domestic honeybees service only 15% of these crops and 80% are pollinated by wild and semi-managed bees, or by other pollinators. Yet, U. S. government agencies gather official economic data only on domestic honeybees, ignoring the value of other pollinators.

We must stop viewing pollination as a "free service" which requires no investment to sustain or protect. In our economic assessments we need to account for the need to protect wild pollinators as a "costs" for maintaining agricultural yields. It is imperative that we conserve wild bees and other pollinators that if properly managed, can hold, stabilize, and even enhance crop yields.

Native prairie can be a pollinator refuge. Be it Conservation Reserve Land, publicly owned land, or privately held areas, native prairie is a goal we are all striving for, and if we do it right we will all benefit.

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ARTHROPOD FAUNA USING MARBLESEED IN WISCONSIN

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Abstract: Many different arthropods use marbleseed (*Onosmodium molle* A. Michaux), in a variety of ways, and several arthropods are restricted to this plant. Surely this is true for other prairie plants as well. The patterns of use of marbleseed by arthropods with special reference to particular species and relationships are presented. Invertebrates comprise the majority of prairie biodiversity. To foster prairie biodiversity, we must accommodate the invertebrate fauna, particularly the specialists that most sharply define a prairie as worthy of our conservation concern. This can best be done by moderating our application of any of the tools of prairie management, spreading the risk inherent in anything we do across time and space.

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Key words: prairie biodiversity, prairie management.

Central to my graduate research (Williams 1996) was marbleseed (*Onosmodium molle* A. Michaux), a prairie plant, and the leaf beetle (*Longitarsus subrufus* LeConte). The study required repeated visits to marbleseed sites and repeated close inspection of marbleseed plants, providing an ideal opportunity to study other fauna using this plant. The results of this corollary research are presented here.

This is not a definitive study of marbleseed's fauna, but simply what was chanced upon in the field and to some extent sorted out in the lab, the library, the museum, and through cooperation with experts in various taxa. Research was conducted in Wisconsin, but marbleseed is widely distributed between the Rocky Mountains and the Appalachian Mountains. The fauna using this plant surely varies from place to place, so this study is incomplete. Another weakness of the present work is that marbleseed's subterranean associated fauna was largely ignored.

Research of this type, even though focused on 1 native prairie plant, can reveal much faunal diversity. This sort of research shows how, from a single organism, relationships quickly ramify out within an ecosystem. It should give pause to those who would depend on the simplicity of mathematical models as a shortcut to understanding. This should awaken prairie conservationists, who tend to think of biodiversity in terms of plants, to the much greater biodiversity present in the invertebrate fauna of prairies, and to the importance of accommodating the needs of the fauna in appropriate and effective land management. The survival of prairie plants does not assure that their suites of specialist invertebrates are also surviving.

Unlike plants, which are fewer in number and much better known, most arthropods cannot be identified in the field. One must collect and curate specimens and then elicit the help of various experts, without whose assistance a study like this is simply not possible. Specimens collected in this study were deposited in the Insect Research Collection at University of Wisconsin—Madison.

Several patterns of use emerge from these data, and some taxa fall into more than 1 category.

FLOWER VISITORS

Arthropods that visited marbleseed are shown in Table 1. Pollination of marbleseed is effected by bees, largely by bumblebees: 6 species were found in this study. Surely other species of bumblebees use these flowers elsewhere. Four species of small halictid bees used these flowers. A single honey bee (*Apis mellifera* Linnaeus) was seen visiting these flowers.

The sole lepidopteran found nectaring at these flowers was the silver spotted skipper (*Epargyreus clarus* Cramer).

The beetle *Meligethes saevus* LeConte is restricted to marbleseed and was found on 30 of the 59 Wisconsin sites in this study. In this genus, larvae develop in flowers, feeding on pollen.

MERISTEMATIC TISSUE VISITORS

Arthropods that used meristematic tissue of marbleseed are shown in Table 2. Meristematic tissue is the tender growing tips of shoots and budding flowers. Typically this part of any plant is more nutritious than older tissue, and these parts are softer. It is not surprising that many fauna were found here. Agromyzid and chloropid flies were abundant. Agromyzid flies of the genus *Melanagromyza* are typically stem miners, so these flies may be reproducing in these stems. The

Table 1. Arthropod visitors to marbleseed flowers, by Order, Family and Species.

Order	Family	Name
Coleoptera	Cleridae	*Phyllobaenus pubescens*
Coleoptera	Nitidulidae	*Meligethes saevus*
Hemiptera	Miridae	*Adelphocoris lineolatus*
Hemiptera	Miridae	*Plagiognathus obscurus*
Hemiptera	Miridae	*Plagiognathus politus*
Hemiptera	Miridae	*Rhinocapsus vanduzeei*
Hymenoptera		unidentified species
Hymenoptera	Apidae	*Apis mellifera*
Hymenoptera	Apidae	*Bombus affinis*
Hymenoptera	Apidae	*Bombus bimaculatus*
Hymenoptera	Apidae	*Bombus fervidus*
Hymenoptera	Apidae	*Bombus griseocollis*
Hymenoptera	Apidae	*Bombus impatiens*
Hymenoptera	Apidae	*Bombus vagans*
Hymenoptera	Formicidae	several unidentified species
Hymenoptera	Halictidae	*Augochlorella striata*
Hymenoptera	Halictidae	*Augochloropsis metallica*
Hymenoptera	Halictidae	*Dialictus achilleae*
Hymenoptera	Halictidae	*Dialictus admirandus*
Lepidoptera	Hesperiidae	*Epargyreus clarus*

Table 2. Arthropods that used marbleseed meristematic tissue, by Order, Family and Species.

Order	Family	Name
Coleoptera	Cantharidae	*Podabrus tomentosus*
Coleoptera	Cleridae	*Phyllobaenus pubescens*
Coleoptera	Coccinellidae	*Brachiacantha ursina*
Coleoptera	Curculionidae	*Otiorhynchus ovatus*
Coleoptera	Curculionidae	*Gymnetrum tetrum*
Coleoptera	Elateridae	*Ctenicera inflata*
Coleoptera	Elateridae	*Limonius griseus*
Coleoptera	Elateridae	*Melanotus hyslopi*
Coleoptera	Elateridae	*Melanotus morosus*
Coleoptera	Nitidulidae	*Meligethes saevus*
Diptera	Agromyzidae	*Melanagromyza* sp.
Diptera	Chloropidae	unidentified species
Hemiptera	Aphididae	*Brachycaudus cardui*
Hemiptera	Cercopidae	*Clastoptera proteus*
Hemiptera	Miridae	*Plagiognathus obscurus*
Hemiptera	Miridae	*Plagiognathus politus*
Hemiptera	Reduviidae	*Phymata* sp.
Hymenoptera	Formicidae	several unidentified species
Lepidoptera		unidentified species
Lepidoptera	Arctiidae	*Cisseps fulvicollis*
Lepidoptera	Arctiidae	*Ctenucha virginica*
Lepidoptera	Arctiidae	*Halysidota tessellaris*
Lepidoptera	Arctiidae	*Haploa contigua*
Lepidoptera	Arctiidae	*Haploa reversa*
Lepidoptera	Nymphalidae	*Danaus plexippus*
Lepidoptera	Pyralidae	*Herpetogramma* sp.

chloropid flies were feeding on damaged tissue, caterpillar frass, and dead insects.

Lepidoptera include 4 species feeding as caterpillars on this tissue. The most common was *Haploa reversa* (Stretch), which can become so numerous as to preclude seed production in marbleseed by consuming all of the flowers.

The 4 beetle species in Elateridae were attracted to the exudate on these hairy young stems, as they are to exudates produced by many plants. Probably other species of click beetle, not chanced upon in this study, also use marbleseed in this way.

The most interesting story among these particular animals again centers on the exudate produced by these young tissues. Four species of Lepidoptera visit these shoot tips and inflorescences before, during and after flowering to run their probosces over the slightly sticky hairs. Three of these are arctiid moths: *Cisseps fulvicollis* (Hubner) and *Ctenucha virginica* (Esper) are common day-flying moths, the former is very common about marbleseed. *Cisseps fulvicollis* moths are also attracted to necrotic plant tissue and they are active at night, to a lesser degree, as well. *Halysidota tesselaris* (James E. Smith) flies only at night. Monarch butterflies (*Danaus plexippus* (Linnaeus)) are often on marbleseed running their probosces over these hairy young tissues. These animals may be gleaning some chemical other than simply sugar to sustain themselves; they may be finding a chemical they can use in their pheromone communication with potential mates, for example. This would be an excellent study for a chemical ecologist.

GENERAL LEAF FEEDERS

Arthropods that feed on leaves of marbleseed are shown in Table 3. The most interesting story among the general leaf feeders centers on the leaf beetles of the genus *Longitarsus*. In Wisconsin, *Longitarsus subrufus* feeds and develops only on marbleseed, and was present at 55 of the 59 Wisconsin sites studied. Some of these marbleseed populations consist of a single plant, yet this beetle is present. *Longitarsus melanurus* LeConte also feeds and develops on marbleseed, but this beetle also feeds and/or develops on two alien members of this plant family: hound's tongue (*Cynoglossum officinale* L.) and blueweed (*Echium vulgare* L.), both of which grow in the same habitat as does marbleseed. *Longitarsus melanurus* was found on 45 of the 59 Wisconsin sites in this study. Two other species of *Longitarsus* beetles were found on marbleseed, one of which may be an undescribed species. Each was found on a single site.

Several species of ants patrol the foliage of marbleseed. Their effects are probably substantial. They no doubt serve, at times, as predators and scavengers. They routinely startle *Longitarsus* beetles from their feeding, and then the ants plunge their faces into the moist leaf tissue, whether for moisture or for some more nutritive substance is unknown.

Table 3: General leaf feeders, by Order, Family and Species.

Order	Family	Name
Coleoptera	Chrysomelidae	*Chaetocnema confinis*, perhaps
Coleoptera	Chrysomelidae	*Epitrix* spp.
Coleoptera	Chrysomelidae	*Longitarsus* spp. 2 species
Coleoptera	Chrysomelidae	*Longitarsus melanurus*
Coleoptera	Chrysomelidae	*Longitarsus subrufus*
Hemiptera	Acanaloniidae	*Acanalonia bivittata*
Hemiptera	Cercopidae	*Philaenus spumarius*
Hemiptera	Cicadellidae	*Aphrodes bicincta*
Hemiptera	Cicadellidae	*Graphocephala teliformis*
Hymenoptera	Formicidae	several species
Hymenoptera	Tenthredinidae	*Dolerus asper*
Lepidoptera		three unidentified species
Lepidoptera	Arctiidae	unidentified species
Lepidoptera	Arctiidae	*Estigmene acraea*
Lepidoptera	Arctiidae	*Grammia virgo*
Lepidoptera	Arctiidae	*Haploa contigua*
Lepidoptera	Arctiidae	*Haploa reversa*
Lepidoptera	Nymphalidae	*Vanessa cardui*
Lepidoptera	Pyralidae	*Herpetogramma* spp., perhaps

GENERAL STEM FEEDERS

Arthropods that feed on stems of marbleseed are shown in Table 4. Except for *Longitarsus subrufus*, which feeds on stem tissue primarily in fall when the leaves are dying, these others tend to feed on younger stem tissue throughout the summer. All Hemiptera have piercing-sucking mouthparts. They feed on plant fluids.

LEAF MINERS

Marbleseed leaf miners are shown in Table 5. Leaf miners feed within a leaf, in the soft interior between the tough upper and lower surface layers. An attempt to rear the fly larvae found mining these leaves failed. The moth *Acrocercops pnosmodiella* (Busck) is a tiny animal that is restricted to marbleseed, or at least to the genus *Onosmodium*. When ready to pupate, it induces the leaf to balloon out, making a small bubble in the leaf. Within this bubble, the tiny caterpillar suspends itself as on a hammock with silk cords, then pupates in midair. This animal was found on very few sites.

STEM MINERS

Marbleseed stem miners are shown in Table 6. The cecidomyiid fly larvae developing in the pith of these stems were reared out, producing large numbers of an undescribed species of *Neolasioptera*; something never before studied. These may well be restricted to marbleseed. The wasps certainly develop within these stems, but whether they are herbivores, or parasitoids, or both is unclear.

ROOT FEEDERS

Marbleseed root feeders are shown in Table 7. These *Longitarsus* beetles feed on marbleseed roots as larvae. This short list reflects the limits of the study, rather than the limits of the root fauna.

PARASITOIDS

Arthropods that are parasitoids and found on marbleseed are shown in Table 8. Parasitoids are animals that develop within the body of another animal, consuming that host animal in the process. The tachinid fly parasitized one of the arctiid moth caterpillars that was taken to rear out. A cocoon of an arctiid moth that was afixed to marbleseed yielded the wasp *Pediobius eubius* (Walker). The braconid wasp emerged from the pupa of 1 of the tiny, leaf mining moths. This wasp was another undescribed species. It may be that this wasp is restricted to this moth, which is restricted to marbleseed or to the

Table 4: General stem feeders, by Order, Family and Species.

Order	Family	Name
Coleoptera	Chrysomelidae	*Longitarsus subrufus*
Hemiptera	Acanaloniidae	*Acanalonia bivittata*
Hemiptera	Cercopidae	*Clastoptera proteus*
Hemiptera	Pentatomidae	*Coenus delius*
Hemiptera	Pentatomidae	*Euschistus servus*
Hemiptera	Pentatomidae	*Euschistus tristigmus*
Hemiptera	Pentatomidae	*Euschistus variolarius*

Table 5: Leaf miners, by Order, Family and Species.

Order	Family	Name
Diptera		unidentified species
Lepidoptera	Gracillariidae	*Acrocercops pnosmodiella*

Table 6: Stem miners, by Order, Family and Species.

Order	Family	Name
Diptera	Agromyzidae	*Melanagromyza* spp., perhaps
Diptera	Cecidomyiidae	*Neolasioptera* spp.
Hymenoptera	Eurytomidae	*Eurytoma* sp., perhaps
Hymenoptera	Eurytomidae	*Eurytoma vernonia*, perhaps

Table 7: Root feeders, by Order, Family and Species.

Order	Family	Name
Coleoptera	Chrysomelidae	*Longitarsus* spp. 2 species
Coleoptera	Chrysomelidae	*Longitarsus melanurus*
Coleoptera	Chrysomelidae	*Longitarsus subrufus*

Table 8: Parasitoids, by Order, Family and Species

Order	Family	Name
Diptera	Tachinidae	unidentified species
Hymenoptera	Braconidae	*Apanteles* sp.
Hymenoptera	Elasmidae	*Elasmus* sp.
Hymenoptera	Eulophidae	*Pediobius eubius*
Hymenoptera	Eulophidae	*Tetrastichus* sp.
Hymenoptera	Eurytomidae	*Eurytoma* sp., perhaps
Hymenoptera	Eurytomidae	*Eurytoma vernonia*, perhaps
Hymenoptera	Platygastridae	unidentified species

genus *Onosmodium*. The elasmid wasp, the *Tetrastichus* wasp, and the platygastrid wasps emerged from stem rearing containers. Platygastrid wasps often parasitize cecidomyiid flies. That the rearing chambers produced many of these flies and many of these wasps and, given that the fly was an undescribed species, it may be that this wasp is also an undescribed species.

Again, the parasitoid may be restricted to 1 host that is itself restricted to 1 plant; this is not an uncommon pattern. Some parasitoids parasitize other parasitoids, so figuring out which tiny wasp is feeding on the plant itself, on some herbivore, or on some other parasitoid, or a combination of these, is a very complicated problem.

PREDATORS

Arthropods that are predators and found on marbleseed are shown in Table 9. Many different spiders were found on marbleseed, some of which were preying on some of the animals previously listed. Some predators hunted over the entire plant, others typically hunted at the shoot tips and about the flowers, where insect activity was usually greatest.

Table 9: Predators, by Order, Family and Species

Order	Family	Name
Araneae		many unidentified species of spiders
Coleoptera	Cleridae	*Phyllobaenus pubescens*, perhaps
Coleoptera	Coccinellidae	*Brachiacantha ursina*, perhaps
Diptera	Asilidae	*Holopogon snowi*
Diptera	Dolichopodidae	*Condylostylus caudatus*
Diptera	Dolichopodidae	*Condylostylus* sp.
Hemiptera	Miridae	*Plagiognathus obscurus*, perhaps
Hemiptera	Miridae	*Plagiognathus politus*, perhaps
Hemiptera	Miridae	*Rhinocapsus vanduzeei*, perhaps
Hemiptera	Nabidae	*Nabicula subcoleoptrata*
Hemiptera	Nabidae	*Nabis* sp.
Hemiptera	Pentatomidae	*Podisus maculiventris*
Hemiptera	Reduviidae	*Phymata* sp.
Hemiptera	Reduviidae	*Sinea diadema*
Hymenoptera	Formicidae	many unidentified species, perhaps
Odonata	Coenagrionidae	*Enallagma carunculatum*

Table 10: Species using marbleseed for its structural properties, by Order, Family and Species

Order	Family	Name
Araneae		many unidentified species of spiders
Diptera	Asilidae	*Holopogon snowi*
Diptera	Dolichopodidae	*Condylostylus caudatus*
Diptera	Dolichopodidae	*Condylostylus* sp.
Hymenoptera	Vespidae	*Polistes fuscatus*
Lepidoptera		unidentified species
Lepidoptera	Arctiidae	unidentified species

SPECIES USING MARBLESEED FOR ITS STRUCTURAL PROPERTIES

Arthropods that use marbleseed for its structural properties are shown in Table 10. Many spiders build webs in marbleseed to capture prey, to shelter themselves during rest and during molting, and to shelter their eggs and young.

The tiny robber fly (*Holopogon snowi* Back) was using dead stems as lookout posts from which to sortie out after flying prey, just as a kingbird does from a telephone wire. That marbleseed provides vertical structure in prairie throughout the year is another way in which this plant participates in the prairie community. This example shows why it is important not to mow or burn most of a prairie at 1 time, for to do so strips away much of the diversity of microsite and of vertical structure.

Dolichopodid flies typically use leaves as perches from which to sortie out after flying prey.

The common paper wasp (*Polistes fuscatus* Fabricius) used marbleseed to support its nest, as did the only vertebrate found using this plant, a song sparrow (*Melospiza melodia* Wilson). In each case, a single nest was found.

The lepidopteran species were 2 larvae found spinning silk platforms slung below individual marbleseed leaves. Whether they were preparing to pupate or to feed is unknown. The arctiid species was a single cocoon, found afixed to marbleseed, from which emerged 77 tiny parasitic wasps, *Pediobius eubius*. These lepidopterans may not feed on marbleseed. All that can be said is that they appreciated this plant for its structural properties.

TAXA SPECIFIC TO MARBLESEED

Table 11 summarizes information on these taxa presented above.

CONCLUSION

Many different arthropods use this 1 prairie plant, and this is certainly true of other prairie plants as well. Several arthropods are restricted to this 1 prairie plant. This is probably true of other prairie plants as well.

In our past efforts to conserve prairies, we generally focused our attention on the flora, which still serves as a useful indicator of biodiversity. But the diversity of invertebrate fauna is much greater than that of the flora on any given prairie. The survival of prairie plants may not mean that their suites of specialist invertebrates are also surviving.

In our management of prairies, we would be wise to moderate our activities to lessen the possibility that in our enthusiasm we eradicate some of the invertebrate species present, particularly the

Table 11: Taxa specific to marbleseed

Order	Name
Coleoptera	*Longitarsus* spp., leaf beetles, 2 species, perhaps
Coleoptera	*Longistarsus subrufus*, leaf beetle
Coleoptera	*Longitarsus melanurus*, leaf beetle, using 2 aliens also
Coleoptera	*Meligethes saevus*, flower beetle
Lepidoptera	*Acrocercops pnosmodiella*, leaf mining moth
Hymenoptera	*Apanteles* sp., parasitoid of above moth, perhaps
Diptera	*Neolasioptera* sp., stem mining fly, perhaps
Hymenoptera	*Platygastridae* sp., parasitoid of above fly, perhaps
Diptera	*Melanagromyza* sp., stem mining fly, perhaps

specialists that most sharply define a given prairie as worthy of our conservation concern. Through immoderate application of haying, grazing and especially fire, we may be actively damaging prairies by simplifying their biodiversity. It is prudent to spread the risk inherent in any management practice across space and time.

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AWAKENING

Come out on the prairie, come walk with me;

I'll show you the light in the wings of a bee.

We'll study the flowers, both grasses and forbs,

And encounter more beauty than our souls can absorb.

Focus and rest, focus and rest,

We'll walk 'til we tire, then nap fully dressed,

To dream of the wind, the light, and the sun,

Anemone, Geum, Andropogon,

To witness our neighbors, commune with our peers,

And awaken refreshed, at peace, without fears.

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EFFORTS TO RESTORE PRAIRIES IN THE DARBY PLAINS OF OHIO

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Abstract: In the early 1980's, Metro Parks began efforts to locate and restore prairie sites which occur within the 1389-ha (3,433-acre) Battelle-Darby Creek Metro Park. Remnant sites were easily located based on existing vegetation. Restoration has been limited to using only seed representing the native genotype of the Darby Plains to preserve the species and genetics of this original prairie region in Ohio.

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Key words: Columbus Metro Parks, Prairie Peninsula, prairie remnants, tallgrass savanna.

The Darby Plains is an area located in west-central Ohio of approximately 1000 km^2 (385 mi^2) and represents some of the eastern-most extensions of the Prairie Peninsula. Today, only remnants of this original landscape remain, as most of this region was drained and converted to agriculture. Remnant prairies of the Darby Plains currently occur along railroad rights-of-way, township cemeteries, bluffs bordering Big Darby Creek, and in small holdings on private land.

Some have suggested the term "tallgrass savanna" to describe this eastern-most extension of the prairie community (Packard and Mutel 1997). While few savannas remain, large bur oaks are frequently scattered across the landscape of this region. Prairies of this region range from mesic to dry and include several species of grasses and a wide diversity of forbs.

SITE SELECTION

In the early 1980s, Metro Parks began efforts to locate and restore prairie sites which occur within the 1389-ha (3,433-acre) Battelle-Darby Creek Metro Park. Remnant sites were easily located based on existing prairie vegetation. Species such as purple coneflower (*Echinacea purpurea*), gray-headed coneflower (*Ratibida pinnata*), pale-spiked lobelia (*Lobelia spicata*) and big bluestem (*Andropogon gerardii*) are frequently among the last species remaining in remnant sites. Other sites were chosen for restoration based on soil types, since many former prairie areas of this region have been plowed and drained for agriculture.

The most extensive soil in the Darby Plains is the Kokomo silty clay loam. This soil is characterized by its dark color, occurrence on nearly level uplands, and very poor drainage (King 1981). Other interspersed soils are typically much lighter in color and occur on the slightest increase in topography in the form of knolls and ridges. These areas are believed to have supported a diversity of mixed oak forest communities, grasslands, and wet prairies at the time of settlement (Gerken and Scherzinger 1979, Steiger 1981).

RESTORATION EFFORTS

Remnant prairie sites have been restored using a combination of manual cutting and stump treatment of woody species, winter mowing, and prescribed burning. Management techniques have varied from site to site based on accessibility, response to management, and the occurrence of other species.

Restoration sites have been restored using only seed representing the native genotype of the Darby Plains to preserve the species and genetics of this original prairie region in Ohio. Numerous descriptions of the Darby Plains dating to the late 1700s and floristic accounts of early botanical surveys (King 1981) have provided a glimpse of the former prairie community of this region. During the late 1970s, the Prairie Survey Project of the Ohio Biological Survey (Cusick and Troutman 1978) discovered numerous relicts which have also been surveyed to provide additional information for the Metro Parks restoration efforts.

Restoration sites were prepared by spraying, plowing and disking. Disking and spraying may be repeated to provide additional control of species such as Canada thistle (*Cirsium canadensis*) which regularly occur on disturbed agricultural soil in this region. Seeds were collected manually and with an Allis Chalmers® Gleaner Series F combine. Seeding takes place during late October and early November. Areas are seeded manually and with a Truax® FLX-812 8-foot end wheel drive no-till drill. A cover crop of winter wheat was also planted, which was mowed the following June.

Restoration sites have been managed primarily by prescribed burning. Areas have been burned as soon after planting as possible, with an initial rotation of annual burning until the prairie became established. After establishment, a 2- to 4-year rotation has been established based on requirements of maintaining desired plant associations. Adjacent unburned areas and mosaic patterns have been left as refuge for other wildlife species.

To date over 40 ha (100 ac) of prairie have been restored. Approximately 35 species of forbs including royal catchfly (*Silene regia*), prairie false indigo (*Baptisia lactea*) and 6 species of grasses including prairie dropseed (*Sporobolus heterolepis*) have been planted successfully. Recent restoration efforts have expanded to include a wetland prairie with prairie cord grass (*Spartina pectinata*), prairie dock (*Silphium terebinthinaceum*) and other sedge meadow/fen species such as queen-of-the-prairie (*Filipendula rubra*), swamp thistle (*Cirsium muticum*) and several species of sedge (*Carex* spp.). This area also provides additional habitat for tiger salamanders (*Ambystoma tigrinum*) which occurs in a nearby pond.

Future plans are to restore 4 areas of at least 25 to 45 ha (60 to 110 ac) in size in a diversity of prairie communities on current park holdings. As the size of these unbroken prairie restoration areas increase, it is hoped that wildlife species such as grassland birds may greatly benefit, since 25 ha (60 ac) is regarded as minimum acreage to sustain breeding populations of many species (Herkert et al. 1993). Plans to restore a prairie savanna on a tract with numerous large specimens of burr oak (*Quercus macrocarpa*) and excellent adjacent prairie soils are also being made.

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PRAIRIE RESTORATION IN MINNESOTA: WHAT'S BEEN DONE AND PLANS FOR THE FUTURE

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Abstract: We report on past and future prairie restoration efforts in Minnesota by various groups. Thirty-five field offices responded to a mailed questionnaire regarding various aspects of prairie restoration activity. Restoring and creating greater diversity to the landscape was the most common goal of respondents. Most field offices now combine their own local seed. A high percentage (70 - 100%) of the seed harvested is warm season species. Truax drills and mechanical spreaders are the most commonly used seeding equipment. Through 1997, nearly 45,000 acres (18,000 ha) have been seeded. Seeding goals for the next 5 years (1998-2002) are 17,500 acres (7,000 ha). Growing season seedings are favored 2 to 1 over dormant season seedings. Habitat types restored are biased towards mesic sites (75%) with dry and wet sites at 20% and 5%, respectively.

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Key words: landscape diversity, questionnaire, Truax drills.

The state of Minnesota was originally blessed with a vast array of prairie lands. It is estimated that there were nearly 18 million acres of prairie at the time of European settlement and now less than 1% remains (Coffin and Pfannmuller 1988, Minnesota Volunteer Staff 1989). With this much prairie land converted to other cover types, it stands to reason that there is significant opportunity for prairie restoration work. Here, we report on prairie restoration efforts in Minnesota which have been completed and the outlook for future restoration efforts.

Prairie restoration efforts are being carried-out by numerous agency groups and private organizations as well as private citizens. This paper addresses work done by agency personnel and The Nature Conservancy. Although The Nature Conservancy is a private group, they often work cooperatively with agency personnel on various prairie ventures.

Since the 1980's, prairie restoration work has become a more substantial portion of the annual workload for many agency personnel. Even though the effort in the field has greatly increased, a state-wide or even region-wide coordination and general overall record-keeping of these efforts has not occurred.

METHODS

A questionnaire regarding goals of restoration work, accomplishments, future plans, seed sources and techniques was sent to field offices of the following groups: Minnesota Department of Natural Resources (MDNR)—Section of Wildlife, MDNR—Section of Ecological Services, MDNR—Division of Parks and Recreation, U. S. Fish and Wildlife Service, White Earth Indian Reservation, and The Nature Conservancy—Minnesota Chapter. Thirty-five field offices responded to our request for information.

RESULTS AND DISCUSSION

Much of the information returned to us was anecdotal in nature but it certainly provides an insight into past efforts and goals for the next 5 years.

Although the term restoration can be used for numerous aspects of prairie landscape work (Packard and Mutel 1997), we mean the act of seeding native prairie species when we use it. A summary of the general goals for restoration work includes the following:

1. Restore and create greater diversity.

2. Develop representative prairie communities (e.g. presettlement conditions).
3. Create cover which is competitive with noxious weeds.
4. Create cover that is low maintenance.
5. Create good stands of native grasses.
6. Create buffer areas around existing high quality prairie.
7. Reduce erosion and reclaim scarred lands (e.g. gravel mines).
8. Restore natural processes.
9. Increase public interest at sites which were formerly monotypes.
10. Advocate and assist prairie restoration efforts on private lands.

Far and away, the major reason for restoration work was to increase the floral (and in turn faunal) diversity of a given tract of land. Many field personnel stressed the need to help others learn about and appreciate prairie, particularly at the local level where most of the dirt work gets done.

Two offices reported restoration work done in the 1960's with the first being done in 1968. Seven offices started restoration work in the 1970's with 12 offices citing the 1980's as the decade in which they started. Another 12 started in the 1990's. Two offices could not locate records of the time period when the first restorations were done in their respective work areas. It must be noted that some of these first restoration were small in size and poor in species diversity, sometimes being composed of only 2 - 3 native grass species. However, we feel they are secure sites at which additional species could be added in future years.

Most seed sources were reported to be from within 100 miles (160 km) of the restoration site. Often the source was even closer; most offices reported combining their own seed or arranging cooperative agreements with local people for custom combining. Much of the combining was done on native prairie units under management of the individual field office. In some cases, harvests have been occurring on older restored sites. As far as combining equipment, Allis-Chalmers® Gleaners are the most popular to use. This brand was followed by John Deere® and Case®. Various types of seed strippers and hand-collection is also used, particularly on tough to get species such as pasque-flower (*Anemone patens*).

The vast majority (70% to 100%) of seed harvested has been warm season species. The main reason for this is the ease of obtaining large volumes of seed from a fairly diverse mix of natives through fall combining. Harvest techniques for many of the early to mid-season species are not as easy. However, this is a very noticeable (on paper and afield) bias which needs to be addressed in future efforts. Many personnel noted that they were returning to restoration sites seeded largely to warm seasons and gradually incorporating cool and mid-season species into these areas. We expect this will become more common in future years.

Nearly all personnel reported similar site preparation methods, especially on oldfield or other non-farmed sites. Typically the area is burned in spring, allowed to green-up and treated with RoundUp® herbicide. Seed is then planted directly into the untilled soil, thereby reducing the need for tillage and the accompanying increased weedy species competition. A wide variety of seeding techniques have been used and include the following: conventional grain drills, Brillion® drills, Truax® drills, mechanical spreaders followed by a harrow, air flow seeders, hand-casting, and hand-casting followed by trampling by cattle or humans. Truax® drills and mechanical spreaders were most often the equipment of choice. The air flow seeders are a relative newcomer to the prairie restoration scene and only 2 offices reported their use. However, personnel from these offices are very optimistic about this equipment as both felt seeding with them has produced their most diverse plantings to date.

Through 1997, nearly 45,000 acres (18,000 ha) of land have been seeded using native prairie. Future plans (1998-2002) call for the seeding of another 17,500 acres (7,000 ha). We believe restoration work in the next 5 years will exceed this goal since we are in an era of opportunity with regards to land available for purchase or cooperative projects. Much of the land that was broken and farmed at a profit in the 1970's was marginal farm land, and it has proved to be an economic burden in recent years. There is a chance some of it may return to grass in the next century.

Respondents favored Growing Season seedings 2 to 1 over Dormant Season seedings. June is the preferred month for seeding. However, more are trying mid- to late-July seedings and are having good results. Habitat types restored are quite biased with 75% of all sites being mesic, 20% dry and only 5% wet. Restoration efforts at these latter 2 types need to be increased to more fully complement our varied landscapes.

Anyone who works with prairie restoration realizes the difficulties facing field managers after the seed has been put into the ground. Planted natives face fierce competition from many weedy non-natives. All personnel agree that reducing weedy competition by mowing (Kurtz 1994), burning (Schramm 1990), or spot spraying are necessary to get a strong restoration. Our largest problem with post-seeding maintenance is the scale of our own effort. Staffing in most field offices has not increased in the past decade but restoration efforts certainly have. Large quantities of land in restoration status have greatly increased workloads. Fortunately, with a little help and substantial patience, natives typically take hold and thrive.

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HORTICULTURAL PRACTICES IN SEDGE MEADOW RESTORATION

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Abstract: Because of the low success rate of temporary and seasonal wetland restorations, the Minnesota Landscape Arboretum has undertaken a model wetland restoration project: Spring Peeper Meadow. The goal of SPM is to create a biologically diverse sedge meadow by introducing over 100 species of sedges, grasses, and forbs as seed, seedlings, or transplants. The site was seeded with 3 separate mixes: lower meadow, upper meadow, and wet prairie. Nineteen species of sedges were propagated. Nearly 70,000 plants were produced and planted in the meadow in 1997.

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Key words: Minnesota Landscape Arboretum, Spring Peeper Meadow, wetland restoration.

In highly disturbed urban or agricultural environments, sedge meadow restorations are cultural situations requiring high levels of management at inception and throughout long-term recovery. In such intensively manipulated environments, horticultural practices can be applied effectively to aid in the restoration of natural systems. Although wetland restoration efforts are now common, years of cultivation in drained prairie potholes throughout the Midwest have resulted in the loss of wetland seedbanks to rely upon for revegetation (Weinhold and van der Valk 1989). In addition, highly fragmented wetland systems likely result in lower rates of propagule dispersion from intact wetlands into restored basins (Galatowitsch and van der Valk 1994). Restorations where water is returned without efforts to revegetate may not necessarily be considered successful. Limited revegetation, for example, precludes the reestablishment of guilds of birds that require meadows (Delphey and Dinsmore 1993).

Because of the low success rate of temporary and seasonal wetland restorations reported for temperate North America (Galatowitsch and van der Valk 1996b), the Minnesota Landscape Arboretum has undertaken a model wetland restoration project: Spring Peeper Meadow (SPM). This project strives to provide information to developers and others who must restore sedge meadow/shallow marsh wetlands. These wetland types are under-represented in restoration efforts within the region (Galatowitsch and van der Valk 1996a). Research conducted at SPM will examine the effectiveness of seeding only versus seeding and planting to restore a sedge-dominated plant community typical of this region. The 3-ha (7.5-acre) sedge meadow restoration is located within the Big Woods/Tallgrass Prairie ecotone (Fig. 1). The goal of SPM is to create a biologically diverse sedge meadow by introducing over 100 species of sedges, grasses, and forbs as either seed, seedlings, or transplants. To this end, 1 of the authors (Bohnen), a horticulturist specializing in production of native plants, was hired to assist in the restoration effort. Nearly 70,000 plants were produced in a greenhouse or nursery and planted in the meadow in 1997.

PLANNING AND SITE PREPARATION

Species selection and placement in the meadow were determined by observing nearby pristine sites and studying species lists from sources such as the Minnesota Scientific and Natural Areas Program (Department of Natural Resources). The species list for Spring Peeper Meadow was created based on the prediction that the site would likely support a temporary or seasonal wetland. Species were grouped to create 3 mixes to sow into the following zones of the restoration: Lower Meadow, Upper Meadow, and Wet Prairie Buffer (Fig. 2 and Table 1). A hydric cover crop mix was sown throughout the Upper and Lower Meadows.

Prior to reintroduction of water, a mature population of reed canarygrass (*Phalaris arundinacea*) growing throughout the restoration site was controlled with a series of applications of the herbicide RoundUp® followed by prescribed burning. The tiles draining the site were broken and inline stoplog water control structures were installed to

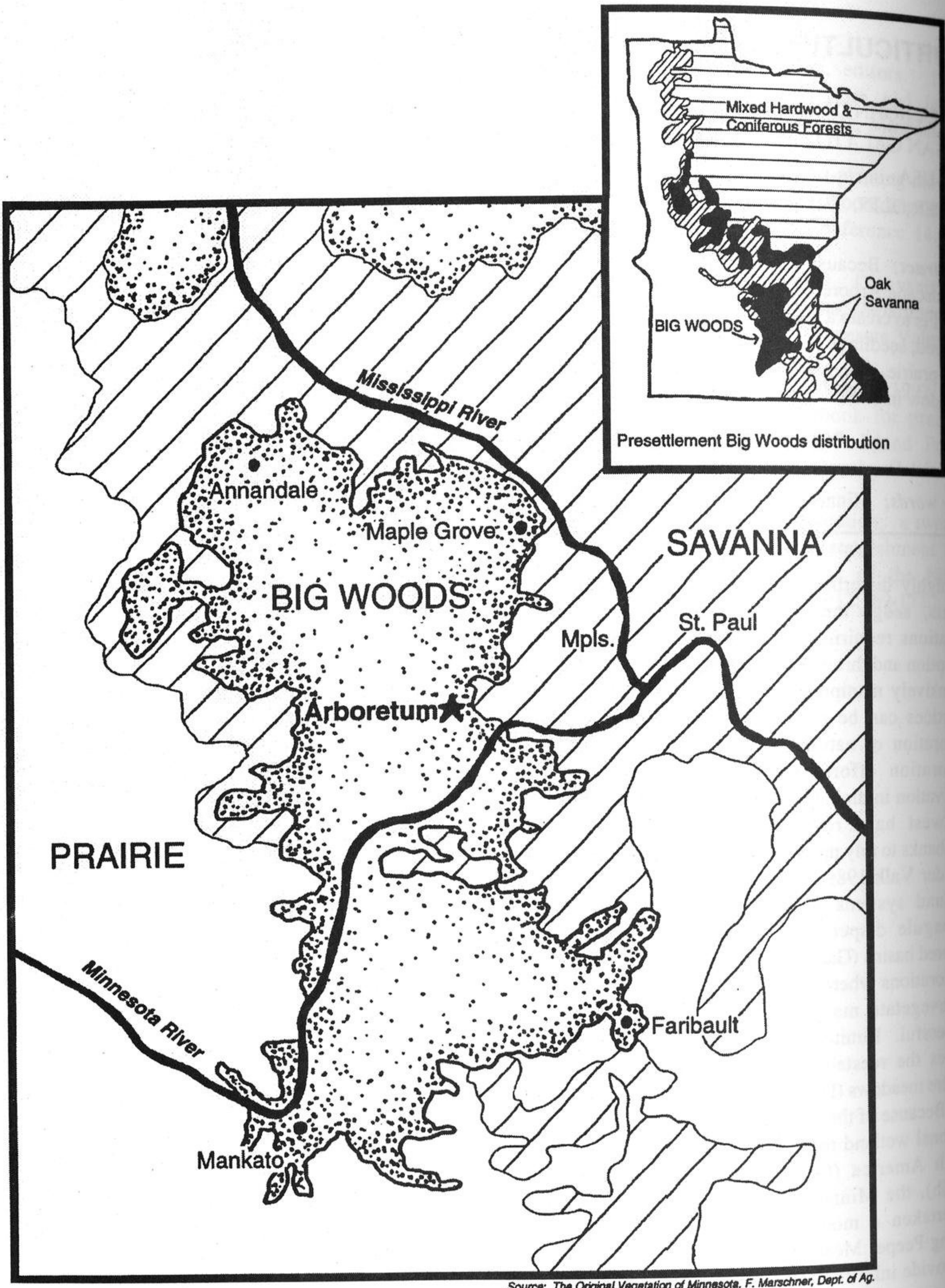

Fig. 1. The location of Spring Peeper Meadow (Arboretum) within the context of its presettlement plant community as determined by Marschner in "The Original Vegetation of Minnesota" (Drawing by F. Rozumalskim 1996, from unpublished report "Arboretum Wetland Restoration Project: Site Analysis").

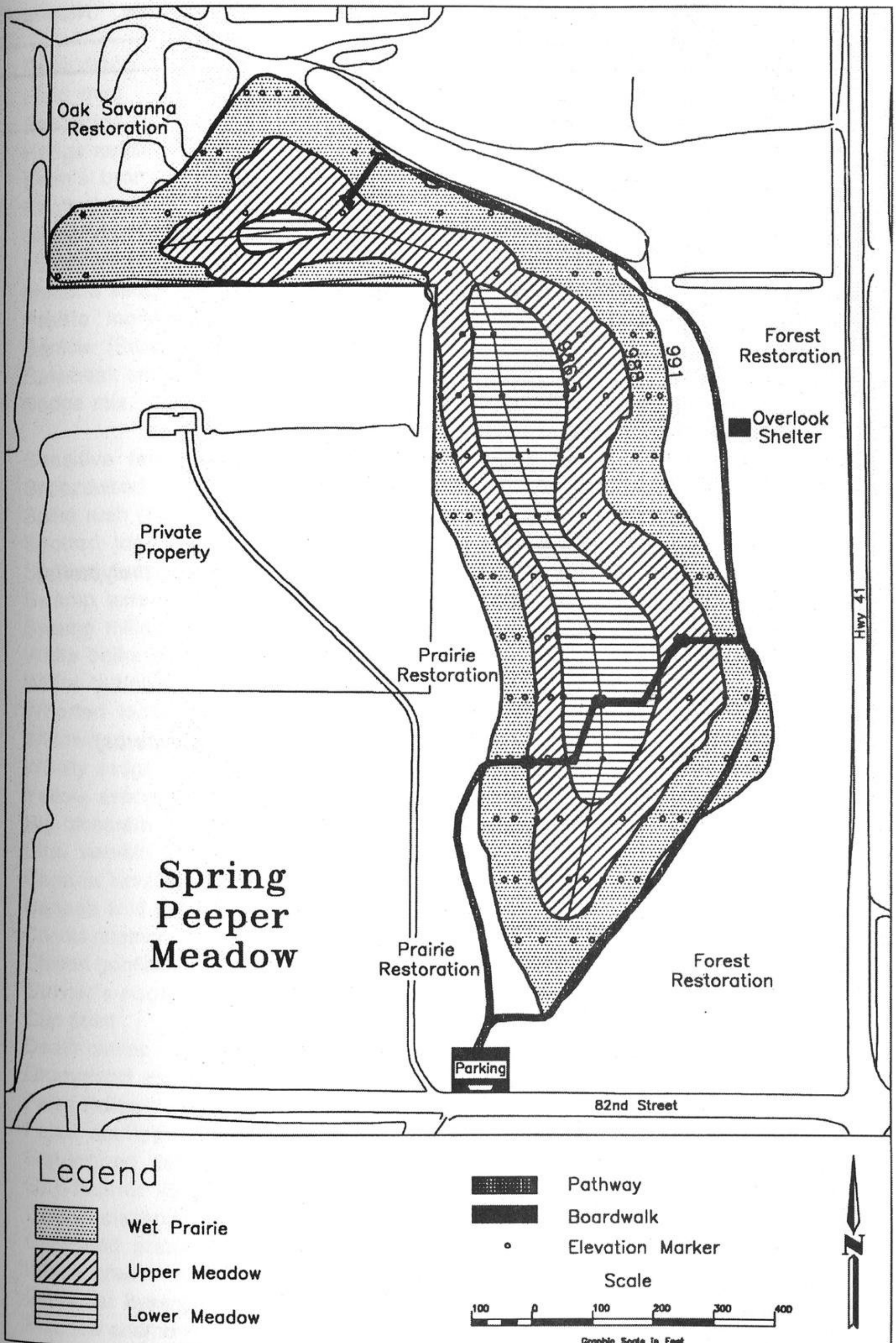

Fig. 2. Spring Peeper Meadow planting zones. The design of the planting zones was based upon predicted high water levels.

Table 1. List of species sown in and/or propagated for Spring Peeper Meadow. Names follow the Atlas of the Flora of the Great Plains (Barkley 1977).

Zone[a]	Common Name	Botanical Name	Prop[b]
CC	Beggarticks	*Bidens spp. (cernua,vulgata)*	S
CC	Bluejoint	*Calamagrostis canadensis*	S
CC	Great water dock	*Rumex orbiculatus*	S
CC	Smartweed	*Polygonum spp. mix*	S
CCP	Oats	*Avena sativa*	S
L	Beaked sedge	*Carex utriculata (rostrata)*	S/P
L	Blue flag	*Iris missouriesis*	S/P
L	Bluntleaf bedstraw	*Galium obtusum*	Sr
L	Bottlebrush sedge	*Carex comosa*	S/P
L	Bulbous water hemlock	*Cicuta bulbifera*	S
L	Common arrowhead	*Sagittaria latifolia*	S
L	Giant bur-reed	*Sparganium eurycarpum*	S
L	Ironweed	*Vernonia fasciculata*	S
L	Lake sedge	*Carex lacustris*	S/P
L	Marsh bellflower	*Campanula aparinoides*	Sr
L	Marsh fern	*Thelypteris palustris (Dryopteris thelypteris)*	Sp
L	Marsh marigold	*Caltha palustris*	Pr
L	Marsh vetchling	*Lathyrus palustris*	Sr
L	Needle sedge	*Carex lasiocarpa*	S/P
L	Retrorse sedge	*Carex retrorsa*	S/P
L	River bulrush	*Scirpus fluviatilis*	S/P
L	Sedge mix	*Carex mix (hystericina, pseudocyperus)*	S
L	Slough sedge	*Carex atherodes*	S/P
L	Soft-stem bulrush	*Scirpus validus*	S
L	Sweet flag	*Acorus calamus*	S/P
L	Tall mannagrass	*Glyceria grandis/maxima*	S
L	Tufted loosestrife	*Lysimachia thyrsiflora*	S
L	Tussock sedge	*Carex stricta*	S/P
L	Water hemlock	*Cicuta maculata*	S
L	Water parsnip	*Sium suave*	Sr
L	Water plantain	*Alisma plantago-aquatica*	S
L	Woolgrass	*Scirpus cyperinus*	S
U	Alleghany monkey flower	*Mimulus ringens*	Pr
U	American bugleweed	*Lycopus americanus*	S
U	American germander	*Teucrium canadense*	S
U	Baltic rush	*Juncus balticus*	S
U	Bebb's sedge	*Carex bebbii*	S/P
U	Blue cardinal-flower	*Lobelia siphilitica*	Pr
U	Blue skullcap	*Scutellaria lateriflora*	S
U	Boneset	*Eupatorium perfoliatum*	S
U	Buttercup	*Ranunculus spp.*	Sr
U	Buxbaum's sedge	*Carex buxbaumii*	P
U	Cinnamon fern	*Osmunda cinnamomea*	P
U	Crested sedge	*Carex cristatella*	S/P
U	Darkgreen bulrush	*Scirpus atrovirens*	S
U	Ditch stonecrop	*Penthorum sedoides*	Pr
U	Dock	*Rumex spp.*	S

Table 1 (Continued)

U	False dragonhead	*Physostegia virginiana*	Pr
U	Field mint	*Mentha arvensis*	S
U	Fox sedge	*Carex vulpinoidea*	S/P
U	Hedge nettle	*Stachys palustris*	S
U	Kalm's brome	*Bromus kalmii*	Sr
U	Knotted rush	*Juncus nodosus*	S
U	Marsh muhly	*Muhlenbergia glomerata*	S
U	Marsh skullcap	*Scutellaria galericulata*	S
U	Meadow sedge	*Carex granularis*	S/P
U	Prairie loosestrife	*Lythrum alatum*	Sr
U	Sanicle (Snakeroot)	*Sanicula spp.*	Pr
U	Saw-beak sedge	*Carex stipata*	S/P
U	Sedge mix	*Carex mix (bebbii, bicknellii, cristatella, molesta, tenera, vulpinoidea)*	S
U	Sensitive fern	*Onoclea sensibilis*	Sp/P
U	Sneezeweed	*Helenium autumnale*	S
U	Spike rush (Spikesedge)	*Eleocharis spp.*	S
U	Spotted joe-pye-weed	*Eupatorium maculatum*	S
U	Spotted touch-me-not	*Impatiens biflora*	Sr
U	Swamp aster	*Aster puniceus*	S
U	Swamp milkweed	*Asclepias incarnata*	S
U	White boltonia	*Boltonia asteroides*	S
U	White turtlehead	*Chelone glabra*	Pr
U	Whorled loosestrife	*Lysimachia quadriflora*	S
U	Willowherb (Fireweed)	*Epilobium spp.*	S
U	Woolly sedge	*Carex lanuginosa (pellita)*	S/P
U	Yellow avens	*Geum aleppicum*	S
WP	Big bluestem	*Andropogon gerardii*	S
WP	Blue vervain	*Verbena hastata*	S
WP	Canada tickclover	*Desmodium canadense*	S
WP	Canada wild rye	*Elymus canadensis*	S
WP	Candle anemone	*Anemone cylindrica*	S
WP	Closed gentian	*Gentiana andrewsii*	Pr
WP	Culver's-root	*Veronicastrum virginicum*	S
WP	Cup plant	*Silphium perfoliatum*	S
WP	Death camas	*Zigadenus elegans*	Pr
WP	Drummond aster	*Aster drummondi*	S
WP	False indigo	*Amorpha fruticosa*	S
WP	False sunflower (ox-eye)	*Heliopsis helianthoides*	S
WP	Flat-topped aster	*Aster umbellatus*	S
WP	Gay-feather (blazingstar)	*Liatris ligulistylis*	P
WP	Golden alexanders	*Zizia aurea*	S
WP	Grayhead prairie coneflower	*Ratibida pinnata*	S
WP	Indian grass	*Sorghastrum nutans (avenaceum)*	S
WP	Lavender hyssop	*Agastache foeniculum*	S
WP	Meadow anemone	*Anemone canadensis*	S
WP	Mountain mint	*Pycnanthemum virginianum*	S
WP	Narrow-leaved goldenrod	*Solidago graminifolia*	S
WP	New England aster	*Aster novae-angliae*	S
WP	Pale-spike lobelia	*Lobelia spicata*	Sr

Table 1 (Continued)

WP	Prairie phlox	*Phlox pilosa*	Pr
WP	Panicled aster	*Aster lanceolatus (simplex)*	S
WP	Prairie cordgrass	*Spartina pectinata*	S/P
WP	Purple meadowrue	*Thalictrum dasycarpum*	S
WP	Purple prairie clover	*Petalostemon purpureum*	S
WP	Rigid goldenrod	*Solidago rigida*	S
WP	Switchgrass	*Panicum virgatum*	S
WP	Tall blazingstar	*Liatris pycnostachya*	S
WP	Tall sunflower	*Helianthus giganteus*	S/P
WP	Turk's-cap lily	*Lilium canadense* ssp. *michiganense*	S
WP	White prairie clover	*Petalostemon candidum*	Pr
WP	Wild bergamot	*Monarda fistulosa*	S
			S

[a] Zone Codes: CC = Cover crop on upper and lower meadow, CCP = Cover crop on wet prairie, L = Lower meadow, U = Upper meadow, WP = Wet prairie.

[b] Propagule Codes: P = Plants produced, planted on site 1997, Pr = Plants produced (sensitive forbs), S = Seeds sown on site, Sr = Seed of limited quantity, sown on site, Sp = Spores sown on site.

manage water levels. In October and November 1996, the site was seeded (Table 2). Seeding in the fall (i.e. dormant seeding) allowed naturally fluctuating winter temperatures to break seed dormancy. In addition, many wet meadow graminoids are cool season plants which begin growth in the cool spring temperatures. Sowing the seeds of these species prior to winter meant there was no delay in seed dispersal and germination due to inability to access the site in early spring. The seed was broadcast on dry ground prior to the spring reflooding of the basin.

GREENHOUSE PRODUCTION OF WETLAND SEDGES

Simultaneous with site preparation, sedges were being propagated for the areas of the wetland that were planted as well as seeded. Nineteen sedges and 8 other taxa were propagated, primarily from seed, but also from rhizomes for reintroduction to SPM. The seeds of nearly 80 species were hand collected and stored dry at about 4° C (39° F) until sown in the field or in the greenhouse. Species such as tussock sedge (*Carex stricta*), bottlebrush sedge (*C. comosa*), fox sedge (*C. vulpinoidea*), and crested sedge (*C. cristatella*) were readily produced from seed, whereas lake sedge (*C. lacustris*) and slough sedge (*C. atherodes*) were not as successfully produced. The failure of some species to germinate is related to seed development. Many apparently sound seeds do not contain a viable embryo (Budelsky and Galatowitsch 1999). Seed development and viability is variable from year to year. Species which have viable seed, yet do not germinate, may require complex treatments to promote germination. Species selected for propagation were those which were thought less likely to successfully germinate in the field in the restoration site.

Table 2. Approximate weights of seed sown on site, October and November 1996.

Zone	Seed Wt. lb/Zone	Seed Wt. lb/Acre	Acres
CC	296.46	39.50	7.5
CCP	179.99	25.40	7.1
L	119.93	42.80	2.8
U	104.95	22.30	4.7
WP	91.98	12.95	7.1

Standard horticultural practices were used to produce sedge seedlings in the greenhouse. In 1996, 15,400 plants were produced to establish a wetland nursery. In 1997, an additional 35,000 plants were produced in the greenhouse to be planted directly into the restoration. Sedge seeds were sown on the surface of Pro-mix® (a peat-based potting mix) mixed with coarse vermiculite in approximately a 4:1 ratio. The flats were drenched with the fungicide Rovral® and watered. These flats were then covered with sheets of plastic and stored in a root cellar for 5 to 11 weeks of cold damp stratification (Bohnen 1994). Temperatures in the root cellar fluctuated from -4° to 2° C (25°

to 35° F). This moist cold treatment breaks seed dormancy and increases uniformity of seed germination (Hartmann and Kester 1975).

Some sedge species have very low germination rates, so the flats were sown densely to save space in the root cellar and in the greenhouse. For species with high germination rates, transplanting began 2 to 3 weeks after the flats were placed in the greenhouse to begin growing. For a sedge such as lake sedge, which germinated poorly, sporadic germination took place over a period of several weeks. However, for sedges such as crested sedge, fox sedge, Bebb's sedge (*C. bebbii*), and bottlebrush sedge germination was quick and uniform. Germination was more rapid in the more humid poly greenhouse than in the brighter, better ventilated exolite greenhouse.

Supplemental lighting was provided to lengthen the day to 12 to 14 hours. Plants were fertilized using Excel® 20-5-21 at a rate of 200 ppm once they were established. In our experience, the sedges could be watered freely with no concern about root rot diseases.

Insects were never found on sedges produced for SPM, however a heavy infestation of thrips on tussock sedge was seen in another greenhouse production operation.

In 1996, some seedlings were transplanted into larger containers (bands) to grow for transplanting into a raised bed nursery. Vigorous plants were produced in the 7.6-cm x 7.6-cm x 15.2-cm (3-in x 3-in x 6-in) bands. However, these occupied too much space to be utilized efficiently for the production of the number of plants required for the SPM restoration.

The production of the sedge plants was scheduled to ensure that healthy, appropriately sized plants were transplanted into the restoration. At least 9 weeks of greenhouse growth were scheduled for the Upper Meadow species that were planted as seedlings. The seedlings that were transplanted directly into the restoration were produced in cell packs (72 cells per flat). Plants grown too long in cell packs became rootbound and quickly desiccated in the greenhouse. Cell packs produced a 15-cm to 25-cm (6-in to 10-in) tall plant for the Upper Meadow. They were quick and easy to transplant and suffered little or no shock.

NURSERY PRODUCTION OF WETLAND SEDGES

We produced 35,000 large transplants for planting in the Lower Meadow (the deeper water area of the restoration). To create a raised bed nursery for production of the transplants, a soil berm was built around a 3.7-m x 1.2-m x 0.3-m (12-ft x 4-ft x 1-ft) template frame which was lined with 4-mm poly and filled with a 15-cm (6-in) layer of topsoil. The template was lifted out after construction of each bed and used to create a series of adjoining beds. Sedges grown in both bands and cell packs were transplanted into the raised beds. We planted approximately 9,300 seedlings into 104 beds. The beds were flooded using a drip-tape irrigation system. Three 1.5-cm (0.63-in) diameter drip tapes ran down each row from a 5-cm (2-in) main. Irrigation was run for 6-hour periods, typically twice a week.

This nursery system was intended to be temporary in design and function since the planting of SPM was scheduled to occur within 1 season. The Lower Meadow species were robust and had quadrupled in size after 1 season in the raised beds. By the beginning of the second growing season, the plants were able to be divided. The number of divisions was species dependent. For example, a 1–year–old bottlebrush sedge could be divided into 4 or 5 pieces. On average, each original lake sedge plant produced 3 large divisions. Production efforts were successful despite some shortcomings in the nursery design. Some beds had holes in them from the building or planting processes, and the poly began to break down where it was exposed to the sun. In addition, the irrigation system did not deliver water evenly. The far end of each row received less water than the near end. These factors had an affect on the number of divisions obtained from the nursery.

PLANTING THE RESTORATION SITE

Strategies for planting the wetland were developed based upon several factors. We assumed high water levels in the basin from the spring snow melt might decrease establishment success if plants were submerged for a long period. Timing of planting also was assumed to influence re-establishment. In addition, maintaining the quality and health of the plants in the greenhouse and nursery for the duration of the planting phase was considered.

The strategy followed at SPM involved planting the smaller greenhouse grown seedlings first in the Upper Meadow and the transplants later in the Lower Meadow. Plants with such small soil volumes (i.e. in cell packs) were difficult to maintain in the greenhouse as spring progressed. Planting began in May in the Upper Meadow, and followed the water level down. The greenhouse grown seedlings were placed outdoors to acclimate prior to being planted by hand in the shallower wetland areas. Seedling planting at SPM was begun on 5 May and completed by 20 May.

Planting began in the Lower Meadow on 20 May. The nursery grown stock was planted after the seedlings because it was easier to maintain in the flooded beds while the seedlings were being planted. In addition, by mid May, the nursery stock was more fully leafed and better suited to being planted into inundated areas. These large nursery grown plants were divided just prior to planting. Planting in deeper water areas of the wetland continued until high water levels from heavy rain in July forced the postponement of planting. At this time, more than 90% of the planting was completed.

Overall, establishment of Upper Meadow sedges at SPM has been successful. Sedges planted 0.5 m (18 in) apart had closed canopies by the second season. A small percentage of the Upper Meadow sedges failed to re-emerge in spring 1998 when they were inundated by high water levels for several weeks following spring snow melt. Budelsky and Galatowitsch (In Revision) found that newly planted tussock sedge and lake sedge seedlings could not survive flooding for long periods of time.

Plant survival in the Lower Meadow was lower than in the Upper Meadow. Lower Meadow sedges planted in May survived better than those planted in June or July. A small number of newly planted Lower Meadow sedges drowned shortly after being planted in July 1997 when they were inundated following heavy rain. Although the majority of sedges in this zone had grown considerably by late fall, significant losses were realized by May 1998. Recent research conducted at the University of Minnesota corroborates the view that planting date may be very important to the establishment of sedge species (Yetka and Galatowitsch 1998). These studies showed that spring planting of tussock sedge and lake sedge rhizomes was more successful than fall planting. An earlier planting date may allow time for establishment and/or accumulation of renewable underground reserves prior to winter dormancy. Establishment success may also be influenced by other factors, such as water levels, substrate, and wind exposure.

MANAGING FOR SUCCESSFUL VEGETATION RE-ESTABLISHMENT

Mechanical and chemical methods of management have been used to control invasive species to give planted vegetation the opportunity to establish. Hand weeding was used extensively in 1997 to control the seedling populations of reed canarygrass and cattails (*Typha* spp.). Nine staff persons shared the daunting task of managing invasive species. In 1998, the area was staffed by 5 persons and control focused more on spot treating with the herbicide Rodeo® as populations of the invasive species have matured and become more rhizomatous. Hand weeding has continued to be used in standing water. Water level management is also used to manage weeds, in particular the germination of cattails, by reducing the area of exposed mud. The management plan for SPM anticipates the continued reduction of labor to maintain the restoration after an initial establishment period.

SUMMARY

The Spring Peeper Meadow restoration is the site of long-term research to be conducted by 1 of the authors (Galatowitsch). Her research will examine ecosystem recovery in relation to mode of revegetation. The success of the horticultural techniques used in restoring Spring Peeper Meadow will be judged in relation to the success of the regeneration of a diverse sedge meadow/shallow marsh plant community and its associated fauna. The level of production, planting, and management done at SPM required significant funding and commitment. Whether planting sedge meadows and shallow marshes should be advocated depends on whether sites restored in this manner recover faster or more completely. It remains to be seen if planting accelerates recovery or improves quality over more traditional revegetation methods such as seeding or passive revegetation from dispersal or seedbanks.

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EPIPHANY

I felt the same blush knowing that I might
Again chance to flush that autumnal sprite
Up from the verdure along by the slough
Rare beyond measure the yellow rail flew.

But rapture sublime came not at the sight
Of a rail this time but rather delight
that this chance alone induced the same thrill
communion alone out under the hill.

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PRESERVATION OF RAILROAD RIGHT-OF-WAY PRAIRIES IN EAST CENTRAL ILLINOIS

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Abstract: One-hundred and fifty years after early Caucasian settlers first passed through what is now Illinois, there is little left of the rich prairie that mellowed the soil. In Champaign County alone, where there were once 600,000 acres of prairie, there is now not 1 intact acre of original prairie. It is in this context that we attempt to save native plants and wildlife in constant competition with agricultural and urban development. We form partnerships to serve and nurture prairie materials and educate society about the need to maintain our prairie gene pool. We gather up old railbeds and upgrade the small elements of prairie that remain along the rights-of-way. We also use these sites to educated young citizens who often know very little about the native plants and animals they have inherited. For them the plants we try to save are often the "weeds and seeds" Americans have been trying to get rid of for 6 generations. Here I present current national, state and local "greenway" efforts to preserve, restore and interpret prairie sites, and how we integrate our efforts with those of other agencies that jointly use (but sometimes abuse) some of the only prairie remnants that remain in this rich agricultural region.

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Key words: Champaign County, greenway partnerships, tallgrass prairie.

During the last 50 years, Illinois has lost a large percentage of its last remaining prairie. Small remnants survive but many are disturbed, disjunct and vulnerable.

Several waves of agricultural advancement and urban expansion have been responsible, starting with drainage, continuing with the invention of a prairie plow and followed by mechanization and chemicalization. Mixed cropping and livestock farming gave way to cash monocrops and valuable fence-line prairies disappeared. Now farms are being consolidated, and corporate ownership is common and small niches are being lost. Urban sprawl and industrialization has added its own challenge. The result is that there is little prairie left. Most of our remaining prairie is to be found along railroad rights-of-way (row), yet the adjacent roads are widened out of the railroad rights-of-way rather than out of croplands on the other side of the road. Champaign County recently lost its last relatively intact acre out of 600,000 acres (240,000 ha) of presettlement prairie to road widening.

Low Awareness

Settlers came to the Midwest from many backgrounds. They settled where they felt comfortable: the Irish on rolling moraines, like home, and the Deutschlanders on the lowlands, which they knew how to drain. Others settled by happenstance or had their own particular guidelines. They all had to face harsh challenges, and for 6 generations these settler families have been getting rid of the prairie biodiversity we want to save. Many farm heirs still do not have a great deal of sympathy for our prairie preservation concerns. Nor do they seem to realize the extent to which the genetic progenitors of crops like corn and soy beans had to come from gene pools from around the world, and that geneticists had to work on those crops for many years. It is also not readily appreciated that we have a responsibility to preserve prairie to serve future scientists in this or other countries.

There is also a "tidiness" syndrome that has grown exponentially with the invention of the rotary mower that tends to remove prairie in the name of "weed control" and "neatness." The prairie ecosystem is seldom invasive of farmland and natural prairies will never be rectilinear.

It is up to conservationists to help citizens understand our long term aesthetic and scientific concerns for this relatively rare ecosystem.

Railroad Remnant Prairies

Some of our last bastions of prairie are remnants located along railroad rights-of-way (row) that have remained relatively undisturbed for 150 years. Beginning in the 1980's, however, railway deregulation led to the massive abandonment of thousands of miles of railbed. Most of these beds were not preserved for their prairie remnants but returned to farming with a substantial loss of prairie. Fortunately there are many significant exceptions.

The Railbanking Act of the 1980's facilitated the public purchase of abandoned railroad corridors for rail-trail and native greenway preservation purposes. The Federal government realized that railroads were being seriously depleted, and it wanted to save some rail corridors for possible future use, including military use. So the Federal government established a cooperative arrangement whereby the public could buy and make interim trail use of abandoned railbeds, with the proviso that they can be returned to railroading if the need arises. An advantage to the public is that continued public use through railbanking supersedes reversion to the adjacent owners and that the titles are "quieted" as long as the bed is in public use. Title quieting helps: railroad titles can present a legal challenge to acquisition because many railroad titles are reversionary.

Importantly, it was also felt that there was so much public money invested in railroad infrastructure in the 1800's that the public deserved 1 more crack at the use of these beds before reversion and consummation. It should be remembered that railroading is still a viable form of transportation, especially for volume freight such as grain and coal. Retention of railbeds for 1 more public use is therefore as much a railbed conservation measure as it is a functional reuse measure for trails and greenways.

The return of interim trails for railroading is not common, but if it does occur we should not be disappointed. Railroads can carry a lot of freight that can otherwise burden highways and taxpayer pockets. For prairie preservationists, the Railbanking and Interim Trail Use Act has helped natural resource programs preserve many miles of native vegetation. Even if some beds are returned to rail, the native vegetation will remain.

One nagging question that remains is "Why did so many tracks have to be removed?" Much of the impetus stemmed from an era of deregulation during which a number of industries, including railroads and airlines, were deregulated with the political motivation of corporate efficiency and survival. Justifiably, many rail lines were outmoded, obsolete and duplicated. Other lines were marginally useful, but not doing enough business to justify corporate continuance. Feeder lines were especially vulnerable as they had often been allowed to fall into a state of disrepair. State and Federal subsidies had helped for a time, until that maneuver fell into disrepute. Abandonments were then allowed to proceed under the deregulation and consolidation acts of the early 1980's. The process of closure was encouraged by 4 things:

1. Designed hopper car shortages.
2. Unit car trains (125 cars) that could not fit on old elevator sidings.
3. High tariffs in anticipation of possible train derailments.
4. The growing availability and convenience of road transport.

Consolidation

The mainlines remained active and financial viable. Some feeder lines were privatized, but many lines were forced out of business by tactics that encouraged highway transportation. Unfortunately, that transfer of freight to the roads has meant a lot of damage to road infrastructures and a loss to the taxpayers. Politically, there has always been a tenuous and artificial balance between rails, highways, and barges that is dependent on moves of the moment and the relative degree to which subsidies and tax breaks are applied to various aspects of the transportation industry.

Many lines were abandoned quickly and without a great deal of thought for their possible functional re-use. Ecologist May Watts was one of the first to suggest that these corridors be used as trails. The difficulty was that abandonment notices were relatively obscure and once the public realized that tracks were being removed there was typically no recourse to legal preservation of the bed.

Interim Trail Use

A burgeoning Rails-to-Trails movement had a lot to do with extending the concept of Interim Trail use. The concept received federal approval for many of the reasons mention above. The program was administered under the title of the Intermodal Surface Transportation Enhancement Act (ISTEA) by the U. S. Department of Transportation's Interstate Commerce Commission, later to be reorganized as the Surface Transportation Board This program provided financial and advisory assistance for the development of alternative forms of transportation such as hiking and biking. The ISTEA program along with Rails-to-Trails movement has encouraged the implementation of over 1000 rail-trails across the nation. The program has been reinstated, by popular consent, under the acronym of TEA 21. The innovative use of this program has helped preserve a great deal of natural and cultural diversity.

States and local agencies have supported the federal rail-trail and greenways program with their own forms of finance and assistance. Different states administer their programs differently, but most of the Midwestern states have extensive networks of rail-trails. More recently, river corridors and wetlands have augmented the rail-trail and greenway movement.

The success with which the public and private sectors have worked together to acquire railbeds and develop trails has been nothing short of amazing. The move has resulted in a lot of "partnerships" that have created models for natural history and cultural preservation and for which we must be thankful.

Urban Excitement versus Rural Caution

Urban communities have bent over backwards to acquire and develop hundreds of miles of rail-trails on abandoned beds, but rural communities have not been so interested. The soils under the beds are rich and profitable for farming, and there is a strong feeling within the agricultural community that railbeds should revert to the adjacent owners. Rural communities in the Midwest have generally been reluctant to allow rail-trails to supersede farming interests.

Illinois and Indiana have been reasonably forthright about the reversionary rights of adjacent owners when rural trackage is abandoned, even though these states were to remove more trackage than many other states. The result is that there are few long rural rail-trails in downstate Illinois or Indiana. Even so, the Midwest states have been adventurous in establishing rail-trail and greenway complexes.

Rail-trail conversions are not popular in the farming communities of the prairie hinterlands because they are regarded as unnecessary (there already are roads) and an affront to farmland dignity, property rights, economics and taxpayer rights. There are also all manner of anticipated hazards (ranging from littering, to theft, to the invasion of privacy, and rape) that are touted as reasons for denying rail-trail and greenway implementation. Some of these attitudes are a normal response to a "fear of the unknown." More often, however, the farm rhetoric is a cover for a strong desire to return rich prairie soils to "productive" cropping. The challenge is greatest where the tallgrass prairies of east central Illinois grew most bountifully on soils mellowed out of deep glacial tills brought in from the Laurentian shield by glaciation.

To give credence to adjacent owner complaints, there is sometimes a recognizable untoward public behavior on abandoned railbeds. This includes vandalism, theft, dumping, and the invasion of privacy. This has been especially so in the interim period between when the line is abandoned and when the line is developed as a rail-trail. It is interesting to note that much of the untoward behavior is local in origin, and at least some of that behavior is a tacit opposition to the existence of the trail. Research indicates that the actual untoward behavior is invariably less than anticipated, and mostly confined to the early years of the rail-trail's life.

A typical rural response to a request for rail-trail support is, "You not only want to steal our land, but you also want to dip into our tax-paying pockets in order to develop and maintain a trail that is going to destroy our way of life. Don't even think of asking for our support."

Under these circumstances, typical rural voter-based and tax-funded park districts, forest preserves, and conservation districts are not in a position to challenge local opinion, let alone help finance a railbed conversion. The states have responded likewise to some extent, but not without a battle from both sides.

State or public agency reluctance to buy beds or their inability to move quickly leaves the challenge of purchase and early maintenance up to non tax recipient bodies that are poorly financed landtrusts, conservation groups, non-profit entities and individuals. These groups often face an even harder challenge than their governmental counterparts but some groups do buy with the hope that the state and other bodies will eventually purchase the bed and/or finance conservation projects. Even if local, state and federal public agencies are interested, they typically cannot move fast enough or smoothly enough to obtain the bed. When state agencies do decide to buy, they are faced with considerable criticism. They are also reluctant to cover the cost of other bodies holding the resource.

The result is that many potential rural trails and their prairie remnants have been returned to farmland, and now there are few beds left to be abandoned or preserved. Despite this disappointment, there are still small pieces of remnant prairie along active as well as dormant railbeds that could be put back together again as a greenway if not as a trail.

Urban Excitement

By contrast to rural reluctance, urban, local government bodies and citizens invariably work proactively to acquire and develop rail-trails and greenways. For example, the Greater Chicago area has many miles of rail-trails.

In reality, most rail-trails have eventually become cherished corridors that are used extensively. Many small towns that were often dying because of the demise of their railroad have begun to do well again and even the most conservative farmers and businessmen in these towns admit that their communities have benefited substantially from the functional re-use of their railbed. It takes many years for attitudes to change, but today one can visit many successful urban and rural trails. There may be other reasons as to why small rural communities are revitalizing (such escape from the cities), but rail-trails have certainly had a positive impact on the communities through which they move.

The Katy Trail in Missouri

An excellent example of a long distance Midwestern trail is the 200-mile Katy Trail which occupies a railbed between St. Louis and Kansas City, Missouri. The trail attracts numerous visitors, and the community citizens are basically pleased with their trail. Indeed, the locals find the visitors to be friendly as well as a financial asset to the community. The users rent bikes, patronize antique stores, eat at restaurants, stay at bed-and-breakfasts, and buy gasoline. There is also a surprising lack of vandalism on nature trails. The visitors have encouraged locals to think a lot more about their own history and its interpretation, and there is a shared interest and enthusiasm in the information so exchanged. Despite their initial opposition, the small communities through which the trail wends are now supporters of the rail-trail movement.

These communities have also preserved their cultural heritage by functionally adapting and reusing old buildings in such a manner as to include and augment their historic circumstance. New buildings, such as visitor centers, are also modeled to be compatible with their historic settings.

Once again, the advantage to prairie preservationists is that accompanying every rail-trail is a surprisingly natural swath of native vegetation and wildlife habitat.

Heartland Pathways

In east central Illinois, Heartland Pathways, a not-for-profit conservation group, has acquired 33 miles of railbed. We are now working with other agencies to jointly acquire another 25 miles. Some of our richer sites have up to 85 prairie plant species, which is good for our area. As these sites are maintained and managed with controlled burning, weed eradication, and seeding, we hope to dedicate them as nature preserves.

Our most challenging question is "How will we establish a community agency that can care for the resource in perpetuity?"

Heartland Pathways is interested in the eventual community purchase and management of these trails. However, it has not been willing to hand over these rail-trail resources to municipal bodies that are often controlled by constituencies that do not feel positively toward our prairie preservation objectives. Municipalities are in a position to obtain grant money, but that is not enough. We are especially looking for an administrative mechanism which will allow Heartland Pathways to continue some form of involvement in the decision-making process. A landtrust that can be granted municipal equivalency for fund raising purposes is our preferred mechanism. Unfortunately the Midwest has not had a strong track record in the establishment of multi-dimensional landtrusts. Much of the acquisition work has been done by the "buddy" system: this would not please us if the "buddies" do not consider prairie preservation as a major objective of the acquisition.

As yet, we have not developed a legal landtrust. Nor, on the other hand, have local municipal bodies developed a mechanism for contributing financially to the initial purchase and upgrade of rail-trails. Most municipal groups want to keep taxes low and spend as little as possible on trail acquisition and development. This basically leaves the municipality dependent on outside grant money. To add to the confusion, the grant money that is available has often been very unidimensional; i.e. the grant money may be earmarked for bikeways but not for prairie preservation.

It is also unfortunate that most funding agencies require the initial hack work to be done by a "volunteered" or "conscripted" community agency. This means that some agency has to accept responsibility for, and the cost of, early mailings, meetings, and the like. When grant money does arrive, there is also the difficulty that the project must be partially completed before bills can be submitted for retroactive payment. This can be a real challenge for not-for-profit agencies, especially if they do not have a bonding capacity to cover their expenses in the interim.

Changes Coming

Fortunately, the funding situation is changing. Many of the currently available funding agencies are requiring or mandating community "partnerships" and "cooperative ventures" that include the not-for-profit initiators, individual interests, established municipalities, and state agencies working together. The unidimensional funding and prior expenditure requirements of funding agencies are also loosening up. Competitive grants are also giving way in some cases to negotiated grants that have more flexibility.

In recent years, the term "greenways" has also become the functional buzzword for many forms of open space, including roadsides, railroads, rivers, and vacant lots. These sites are often maintained through the use of "greenway partnerships" that involve many agencies and people.

Partnerships are a relatively new approach to land acquisition for management in the Midwest, but they have been receiving accolades. Agencies such as the Federal Natural Resources Conservation Service (NRCS) and state departments of natural resources and conservation have been encouraging exciting local partnerships. These agencies provide a range of technical, planning, and financial assistance that promote local initiatives. There are also urban programs, such as the Federal "Main Street Program," which encourages old town upgrade, historic preservation, and economic viability, that have been very successful. In the Main Street case, federal finance is directed to the state, which in turn provides advisory support services, rather than direct financial assistance, to local communities. Those support services are proving effective in bringing together many groups and individuals who have tended to work independently or in loose-knit coalitions that answer to city and county boards. These coalitions have been quite effective but the partnership programs have helped to bring these groups together and give them focus so they become a more effective administrative body.

It is a case where a little well-informed outside state and federal assistance and support has given strength to interagency involvement. This is especially so where the multi-dimensional use of the resources is important. The State advisory groups help to explain the social mechanisms and merits of a partnerships. They have also been instrumental in emphasizing community strengths. Community differences then often tend to settle themselves as people get together. State involvement also encourages citizens and leaders to get involved in the decision-making process. In this way the partnership, in and of itself, becomes a positive educational experience within the community.

In the case of Heartland Pathways our corridors have many potential uses. They include:

1. Potential freight, passenger, and historic railroading.
2. Utility services such as fiber-optics, gas, water, and sewage.
3. Recreational trails and education.
4. Biodiversity preservation.
5. Cultural preservation.
6. Aesthetic ambiance.

As stated previously, not-for-profit agencies such as Heartland Pathways, that have acquired natural areas which they are interested in turning them over to communities, have a couple of alternatives. One is to turn the resource over to a series of traditional municipal agencies, linked by intergovernmental agreements. The other is to form a partnership or landtrust and retain some form of overall control. The partnership-form of administration is more flexible and more sophisticated as far as Heartland is concerned.

A Potential Preservation Corridor

General details.—Visualize a railbed acquisition with a city at each end and a rail corridor that runs through several towns. The prairie along the bed is low-grade but some of the last left in the area.

On one hand, there is community support for a trail, partially because rail-trails have become popular and partially because there is money available for rail-trail development. Acquiring state and Federal funding is important for small communities; they do not want to spend their own taxes. There is also a tendency for municipalities to allow the trail aspects of the corridor to dominate over the natural and cultural aspects of the corridor, because there is more funding for trails.

On the other hand, there is farm opposition to a prospective trail. Demands are being made that railbeds be returned to agriculture. Adjacent landowners also have a vocal dislike of "weeds," so the corridor is an easy target for invasive mowing, spraying and cultivation. The rural community does not want littering, theft or untoward behaviors of any kind and that is reason enough for not having a trail. At the outset is also not clear that visitors are welcome.

There are dignified old towns along the line that have benefited from turn-of-the-century factories, and inter-urban transportation. There is also a 7-mile active railroad museum in place in the middle of this corridor that has a strong tourist following. Heartland would like to extend the trackage of that museum over our bed, to the nearby Sangamon River, to allow the museum trains to take on water for a steam engine in traditional style. Truss bridges and an expressway underpass add character. There is the potential for the reactivation of the railbed so that tourist trains could run between 2 cities that are 45 miles apart.

Restauranting on the rails is conceivable on another loop. Consideration is also being given to return 4 miles of active railroading to accommodate the movement of grain. That implies the sharing of a truss bridge by low (once a month) frequency grain trains, with hikers and bikers. This suggestion frightens legal authorities, but safety is not a great problem if trains move at night. (We have to learn how to share our dwindling resources with an increasing population of potential users.)

The corridor includes geophysical features that include moraines, kames, outwash plains, and a river the Heartland Pathways trail crosses in 2 places. This provides a bottomland experience that includes riparian forests and recreational opportunities such as fishing and canoeing. Heartland Pathways has also acquired a 30-acre homesite adjacent to the railbed, which we hope to convert to a rest place and a retreat for art, biology, and natural history teaching.

There is also an infrastructural corridor potential on this railbed for fiber optics, power lines, sewage, and water, which could lead to cooperative ventures with local industries and governmental bodies.

There are other matters that involve cooperative caution such as insurance and the sharing of legal risk.

A suggested greenway partnership.—Heartland Pathways can choose between:

1. Assignment of the bed to a number of established municipal bodies, or
2. To establish a greenway partnership.

The administrative mechanism Heartland Pathways is proposing is for a greenway partnership with the details outlined below. But there are many possibilities. Some partnerships are engineered by agencies that have established rules. Others are independent and make their own rules. In any event, the partnership should be compatible with the framework of the political tradition of the area.

The mission of the Greenway Partnership would stress community involvement on the assumption that community involvement results in community commitment. We would ask that contractors especially would take that mission into account and arrange to work in lock step with local citizens and agencies.

Heartland is proposing a partnership greenway with:

1. *Board of Directors.* The board would be composed of 5 members that are broadly committed to the objectives of the proposed greenway. We want a board that will provide a philosophic base and an accessible leadership. The board would be loosely representative of the interest groups concerned including: agriculture, commerce and industry, railroading, natural history, cultural history, recreation, education, municipalities, private agencies and committed individuals. Not all interests could be represented at any 1 time, but the board would be elected to cover a broad spectrum of interests. Board members would be elected to a rotating 3-year term. Board members would not be expected to be operational involvees but that would not deny their practical input. The mission of the board would be to draw multiple threads together across many philosophies and jurisdictions in as many as 8 counties.

   (Note that the board would be intentionally small. This is especially important in the early stages of acquisition and management when meetings have to be called quickly. This is hard work which requires an intense group of interested and committed people. This is not the time for a laundry list of name supporters who are not in a position to be out there when the whips are cracking.)

2. *Executive Committee.* The traditional mechanism of an executive would be established to facilitate board contact and decision making.

3. *Manager.* A manager is essential for a project of this nature to facilitate every day activities and contacts. A part-time position could be appropriate if funds are limited.

4. *Intergovernmental Agreements.* These would be setup by the board to provide a legal base parallel to that of existing municipalities.

(This is mainly an established mechanism to allow a partnership to operate as a special purpose entity with municipal equivalency as far as the making of fund requests and the meeting of state-wide mandates is concerned.)

5. *Associates.* They would be the pragmatists of the Greenway Partnership. They would be the interested parties that would have a vested interest in working with and using the corridor. The associates would include those agencies that have the skills and physical plant to make the corridor work. Prairie preservation, for example, might be handled by a non-profit group of prairie friends. A historic inter-urban depot might be handled by a historic preservation group. Urban activities would be the responsibility of associated municipal agencies. The associates would be the operating caretakers, developers, and users of the greenway.

   The associates would provide their own physical plant and framework for their portion of the greenway.

   Associate membership would be based on a request to the full board. Project adjudication would be based on criteria related to the amount and depth of the commitment to and use and benefit of the greenway. There would be a financial commitment commensurate with the members' involvement. Grant requests and distributions would be prepared by, and approved by, the associates before being adjudicated by the full board. Associate membership would not be limited in number but comprised of all the members involved in the upkeep and use of the corridor.

   An associates board would be elected by the associate members and be composed of 5 members. The relationship between the full board and the associates would be one of coordination across jurisdictional and philosophical boundaries.

6. *Advisors.* A group of technical advisors would be established to help at both the board and associates levels.

7. *Meetings.* Board meetings would be held quarterly. Associate meetings would be held 1 week prior to the Board meeting.

8. *Office.* The board would have an accessible office, manager, and a small physical plant. (There is nothing more frustrating than to have a large project that has no contactable office, manager or equipment.)

9. *Funding.* Funding would be solicited by the Greenway Partnership Board and be redistributed according to requests for proposals made by the Board of Associates then adjudicated by the Greenway Partnership Board.

CONCLUSIONS

A greenway partnership can combine multiple use, community involvement and fiscal reserve. The preservation of prairie remnants through the use of a greenway partnerships is a viable alternative to the unidimensional assignment of natural resources to a battery of municipal agencies along a 50-mile corridor.

Traditional community group and municipal approaches work well, but so do special purpose partnerships. It is merely being suggested that greenway partnerships and landtrusts have proven to be flexible and effective mechanisms for multiple use and community interaction. It is for this reason that partnerships are being encouraged by many funding agencies.

We encourage prairie preservationists to consider the purchase or rental of biodiverse remnant prairies on active or abandoned railroad lines. We also suggest that you keep in mind a partnership mechanism of administration so a range of interested parties can be involved.

DYNAMICS OF A THREATENED ORCHID IN FLOODED WETLANDS

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Abstract: One of the three largest metapopulations of the western prairie fringed orchid (*Platanthera praeclara*) occurs on the Sheyenne National Grassland, in southeastern North Dakota. Our study was initiated in 1993 to quantify the effect of flooding on individual orchid plants. In 1993, 66 plants (33 flowering and 33 vegetative) growing in standing water were permanently marked; their status was checked at the end of the growing season in 1993 and in subsequent growing seasons (1994-1996). Most (70%) of the flowering plants persisted through the 1993 growing season. Those that did not were shorter ($P = 0.001$) and had a higher percentage of their stalk submerged through the growing season ($P < 0.02$). Only one vegetative plant persisted through the 1993 growing season. The ability of flowering plants to persist in standing water was attributed to their greater height which allowed some portion of the plant to remain above the water and produce photosynthates needed to produce next season's shoot bud and immature root system. Flowering plants persisted through the first growing season with as much as 75% of their stalk submerged in water. In 1994, only four plants reappeared; in 1995 only one plant reappeared aboveground. None of the plants that did not persist through 1993 reappeared in 1994 or 1995. By 1996 none of the marked plants were observed aboveground. Although flooding is detrimental, especially to the survival of vegetative plants, its impact must be viewed in a larger context and include data from several years. It is likely that flooding creates suitable moisture conditions on higher landscape positions, provides an important mechanism for seed dispersal, and is one of several natural catastrophic events that plays a significant role in perpetuating these wetland systems and associated species.

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Key words: flooding, North Dakota, *Platanthera praeclara*, Sheyenne National Grassland, threatened plants, wetlands.

The western prairie fringed orchid (*Platanthera praeclara*) is a federally listed threatened plant species found in wetlands of the tallgrass prairie west of the Mississippi River (U. S. Fish and Wildlife Service 1996). One of the three largest metapopulations of the orchid occurs on the Sheyenne National Grassland in the southeastern corner of North Dakota (U. S. Fish and Wildlife Service 1996). The climate in this region is erratic and is characterized by periods of both severe droughts and periodic flooding.

The western prairie fringed orchid is a perennial plant characterized by erratic aboveground growth and flowering. Periods of high orchid numbers, usually linked with above-average precipitation, are followed by years when the orchids have seemingly disappeared (Bowles et al. 1992). The life history of the orchid includes two distinct life states. Vegetative plants on the study area average up to 24 cm tall, usually have 1 or 2 leaves, and remain vegetative throughout the growing season; flowering plants develop a hollow flowering stalk early in the growing season that has numerous leaves (> 10) and average up to 52 cm tall (Sieg and King 1995).

The western prairie fringed orchid was thought to be a long-lived species, with erratic flowering patterns and periods of dormancy (Bowles 1983). However, recent demographic data collected on the Sheyenne National Grassland during a period that included a drought and episodic flooding suggest that most plants live three years or less, and once absent, the odds of remaining absent are 80% or better (Sieg and King 1995). The orchid regenerates vegetatively during the growing season by forming a new primary tuber and perennating bud which develop into the new root system and shoot for the following growing season (Dressler 1981, Wolken 1995). In this manner, populations may persist for some time. However, seed establishment is required for recruitment of new individuals (Bowles 1983).

The association between soil moisture and growth and flowering of the orchid has been documented. Densities of flowering orchids on the

Sheyenne National Grassland were positively correlated with soil moisture in the current year, and total orchid density was correlated with soil moisture in the current and previous year (Sieg and King 1995). However, the dynamics of orchid populations in flooded wetlands are undocumented. Severe flooding on the Sheyenne National Grassland, beginning in 1993 and continuing to a lesser extent through 1996, afforded us the opportunity to assess the impacts of standing water on the persistence of western prairie fringed orchids. The purpose of this study was to determine if orchids that were partially or totally submerged persisted through the 1993 growing season, and if they reappeared aboveground in 1994 and in subsequent years. We were also interested in determining what variables were most useful in predicting survival of orchids in flooded conditions.

STUDY AREA

The study was conducted in the Sheyenne National Grassland, in southeastern North Dakota. The National Grassland encompasses 27,244 ha, and is managed by the United States Forest Service. Kuchler (1964) depicted the vegetation of the Sheyenne National Grassland as tallgrass prairie; however, the "Sandhills Prairie" terminology of Barker and Whitman (1989) is more accurate. Big bluestem (*Andropogon gerardii*) and little bluestem (*Andropogon scoparius*) occur throughout the study area. The western prairie fringed orchid occurs most often in lowland depressions ("swales") associated with the Glacial Sheyenne Delta. A layer of nearly impervious silt interbedded with clay and sand is responsible for the relatively high water table in the swales (Baker and Paulson 1967). Woolly sedge (*Carex lanuginosa* Michx.) northern reedgrass (*Calamagrostis stricta* (Timm.) Koel.), and Baltic rush (*Juncus balticus* Willd.) are common in lowland depressions where the orchid occurs (Sieg and Bjugstad 1994, Sieg and King 1995). Blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths), needle-and-thread (*Stipa comata* Tm. & Rupr.), sun sedge (*Carex heliophila* Mack.), and prairie sandreed (*Calamovilfa longifolia* (Hook) Scribn.) grow on uplands.

The mean annual precipitation on the study area is 497 mm, the major portion of which is received during the growing season months of April to September (U. S. Department of Commerce 1973). Precipitation on the National Grassland was above average in 1992 (608 mm), 1993 (561 mm), 1994 (510 mm), 1995 (602 mm), and 1996 (549 mm). As a result, the National Grassland was severely flooded in 1993 and some swales where the orchid commonly occurs remained flooded in 1994, 1995, and 1996. Although records on flooding on the National Grassland are not available, the Sheyenne River at Lisbon, N. D., has exceeded flood stage 10 times since 1975; four of these dates were since 1993; flooding occurred twice in 1996 (Fig. 1). Eight of these occurrences (80%) were from March to May (National Weather Service unpublished data, on file at the National Weather Service Office, Grand Forks, ND 58203-0600).

METHODS

In order to assess persistence of orchids through periods of flooding, our goal was to randomly select a minimum of 2 vegetative and 2 flowering orchids in each of a total of 15 flooded swales on six sites (Fig. 2). The other criteria was that the water depth at each plant location was at least 5 cm at some point during the growing season. Therefore, we permanently marked and mapped the locations of a total of 66 orchids (33 flowering and 33 vegetative plants) in early July 1993. In addition to recording the life state of each plant, we also measured plant height, number of leaves, number of flowers (for flowering plants), and water depth for each marked plant.

We quantified persistence by revisiting marked orchids late in the orchid growing season (mid-August) in 1993. In addition to assessing orchid health and survival, we again measured water depth at each plant. We visited the marked locations and measured water depth (if standing water was present) during the peak of flowering (mid-July) in 1994, 1995 and 1996 to determine if the orchids reappeared in subsequent growing seasons.

Statistical Analyses

Flowering and vegetative plants were analyzed separately. For each life state, plants were divided into one of two groups: "alive" - those that persisted through the 1993 growing season or "dead" - those that did not persist through the growing season. "Dead" plants included orchids whose aboveground portions were present but severely decomposed, and those whose aboveground portions were entirely rotted off.

Only 1 vegetative plant persisted through the growing season; therefore, we were not able to analyze characteristics of "alive" and "dead" vegetative plants. However, sample sizes for these two persistence classes were adequate to compare characteristics of "alive" and "dead" flowering plants.

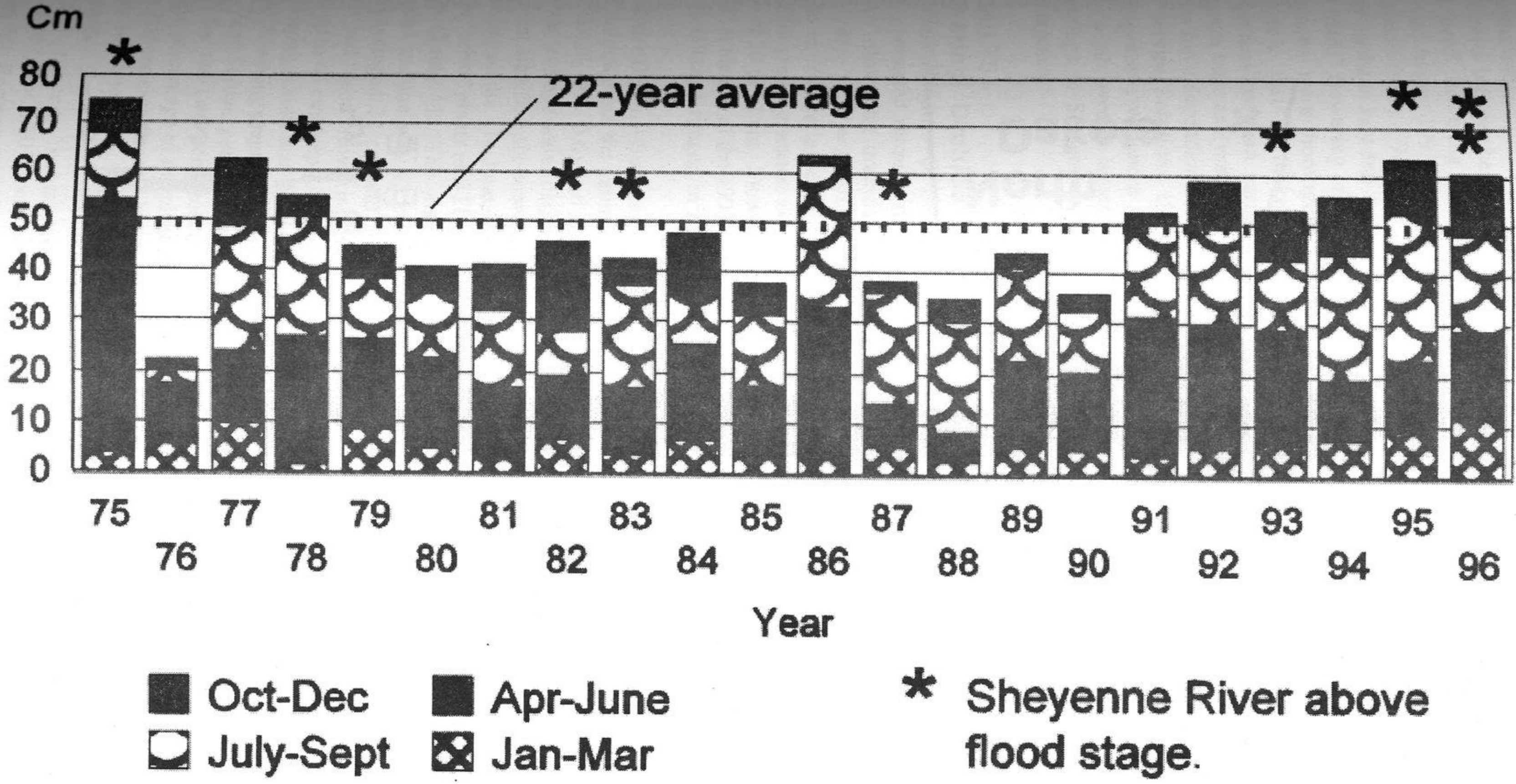

Fig. 1. Total annual precipitation, by season 1975-1996, for Lisbon, North Dakota, near the Sheyenne National Grassland, plus years with one or more times when the flow in the Sheyenne River at Lisbon exceeded flood stage (National Weather Service unpublished data, on file at the National Weather Service Office, Grand Forks, ND 58203-0600).

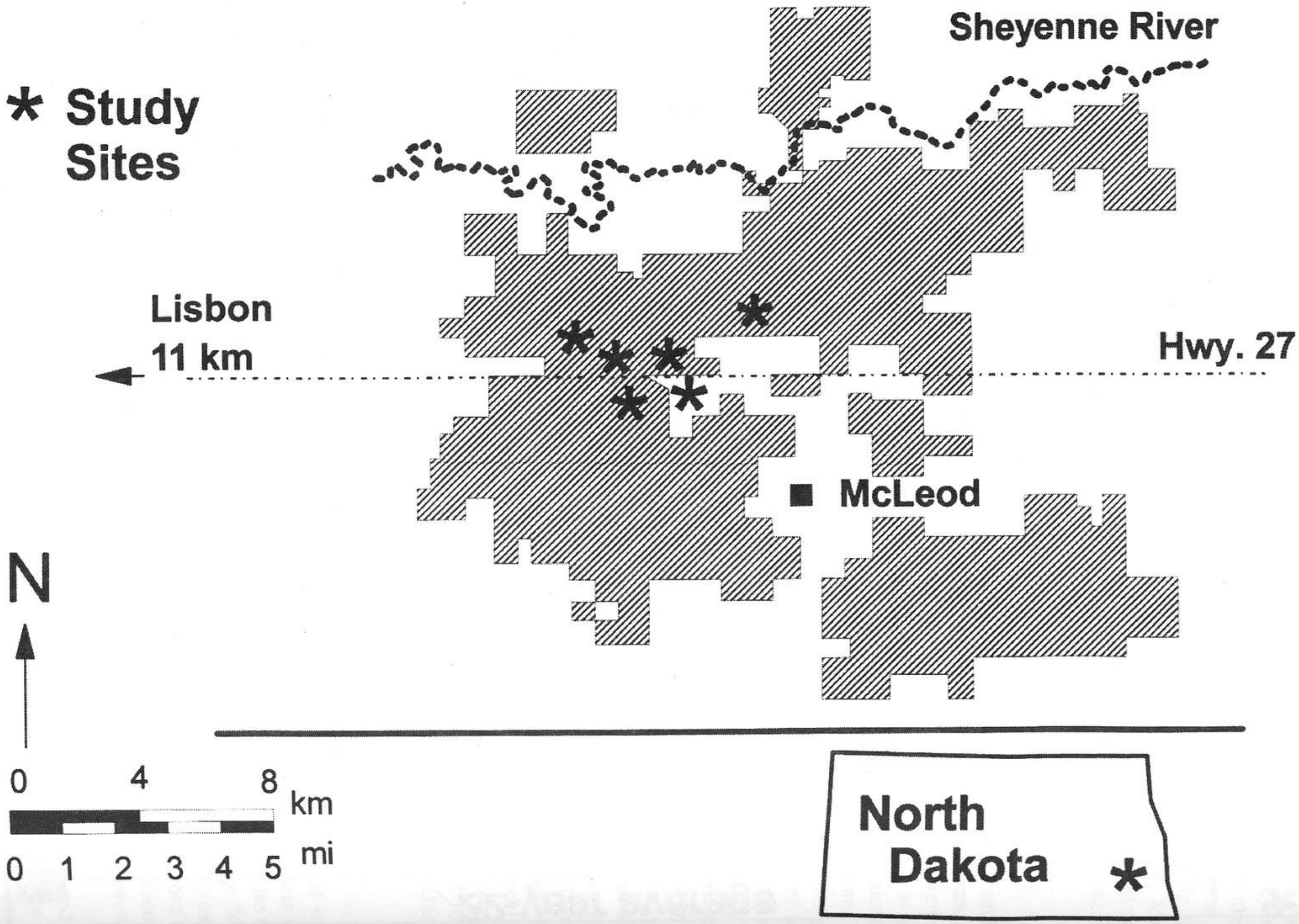

Fig. 2. Location of the study sites on the Sheyenne National Grassland in southeastern North Dakota.

Independent samples t-tests were used to compare differences between heights and percentages of "alive" and "dead" flowering plants that were submerged in July and August 1993 (Statistical Product and Service Solutions 1997). We also used t-tests to compare water depths in July and August 1993 between "alive" and "dead" flowering orchids. The assumption that variances were homogeneous was tested with Levene's test (Milliken and Johnson 1984). Differences between variables with heterogeneous variances were analyzed with heterogeneous variance t-tests for independent samples (Statistical Product and Service Solutions 1997). Variables that had heterogeneous variances ($P < 0.05$) included June water depth, average water depth, plant submergence percentage in September, and average percentage submergence).

RESULTS

Flowering Orchids

Plant Height.—Of the 33 flowering plants, 23 (70%) persisted through the 1993 growing season. "Alive" flowering orchids were significantly ($t = 3.875$, $df = 31$, $P = 0.001$) taller than "dead" plants (Table 1). Flowering orchids that survived through the 1993 growing season averaged 50 cm tall, with a range of 30 to 77 cm. Flowering orchids classified as "dead" at the end of the 1993 growing season averaged 32 cm tall, and ranged in height from 14 to 46 cm tall.

Water Depth.—Standing water was present in the swales throughout the summer. Water depth in June ($t = -0.428$, $P = 0.6$) and September (t -1.12, $P = 0.3$), and average water depth ($t = -.826$, $P = 0.4$) did not differ significantly between persistence classes of flowering plants. In June, water depth averaged 19 cm for "alive" plants and 21 cm for "dead" flowering plants (Table 1). The maximum water depth we recorded in June was 43 cm. In September, water depth averaged 22 cm and 26 cm, respectively, for "alive" and "dead" flowering plants; but, we measured water up to 46 cm deep. Average water depth through the growing season was 20 and 24 cm for "alive" and "dead" flowering plants, respectively.

Plant Submergence.—In spite of similar water depth for the two persistence classes of flowering orchids, percentage of the plant that was submerged in water differed significantly between "alive" and "dead" plants in June ($t = -2.802$, $P = 0.009$) and in September ($t = -2.660$, $P = 0.02$), and the overall average percent submergence also differed ($t = -3.067$, $P = 0.001$) between the two persistence classes for flowering plants (Table 1). Percentage submergence in June averaged 35% for "alive" plants, with a maximum of 73%, compared to 66% for "dead" plants, with a maximum of 100%. The percentage of "alive" plants that was submerged in September averaged 43%, with a maximum of 75%, compared to 91% submergence for "dead" plants, with a maximum of 100%. The average percentage submergence through the growing season was 40% for "alive" plants and 78% for "dead" plants.

Vegetative Orchids

Only one vegetative orchid persisted through the 1993 growing season. This plant averaged 23 cm tall and was found in water that averaged 6 cm deep in June (Table 2). By the end of the growing season, the water was < 1 cm deep. "Dead" vegetative orchids averaged 19 cm tall, and occurred in water that averaged 15 cm in June and 18 cm in September. The percentage submergence for "dead" vegetative plants averaged 90% in June and 100% in September. In some cases, we found little of the plant by the middle of August 1993. All of the submerged plants had some partially rotted leaves; some plants were totally rotted.

Subsequent Growing Seasons

Of the 23 flowering plants that persisted through the 1993 growing season, only three reappeared aboveground in 1994 (Table 3). The average percentage of submergence for these three plants in August 1993 was 28%, compared to an average submergence of 45% for the 20 plants that survived through 1993 but did not reappear in 1994. Two of the flowering plants returned as vegetative plants in 1994 and 1 flowering plant returned as a flowering plant in 1994. The one vegetative plant that persisted through 1993 reappeared as a vegetative plant in 1994. By the time we revisited the marked plants in 1994, other swales on the study area remained flooded, but standing water was not present at the marked orchid locations.

In 1995, we found only one of the originally marked orchids, and in 1996 none of the originally marked orchids appeared aboveground. Standing water was again present in most swales in both July 1995 (ranging from an average of 4.0 to 18.8 cm deep) and July 1996 (ranging from an average depth of 0 to 33.0 cm) on these study sites when we checked marked orchids in July. None of the 42 plants that did not persist through the 1993 growing season reappeared in the three subsequent growing seasons.

Table 1. Average plant height (± SE), water depth in June and September, and percentage submergence of plants in June and September, plus overall average water depth and average percentage submergence for 33 flowering western prairie fringed orchids occurring in flooded swales, by their status (alive or "dead"[a]) at the end of the growing season in 1993.

	Alive (n=23)	"Dead"[a] (n=10)
Plant height (cm)	49.5 ± 2.6[b]	32.4 ± 3.1[c]
June water depth(cm)	18.8 ± 3.1[c]	20.9 ± 3.6[c]
June plant submergence (%)	35.2 ± 4.9[c]	65.5 ± 12.0[b]
September water depth (cm)	21.5 ± 2.4[c]	26.0 ± 2.7[c]
September plant submergence (%)	42.7 ± 3. 8[c]	91.1 ± 17. 8[b]
Average water depth (cm)	20.1 ± 2.7[c]	23.5 ± 3.0[c]
Average plant submergence (%)	38.9 ± 4.0[c]	78.3 ± 14.0[b]

[a]"Dead" plants were those whose aboveground portions were present, but severely decomposed, or whose aboveground portions were entirely rotted off.

[b, c]Means followed by different superscripts are significantly different (P <0.05).

Table 2. Average (± SE) plant height, water depth in June and September, and average percent plant submergence in June and September, plus overall average water depth and average percent plant submergence for 33 vegetative western prairie fringed orchids occurring in flooded swales, by their status (alive or "dead"[a]) at the end of the growing season in 1993.

	Alive (n=1)	"Dead"[a] (n=32)
Plant height (cm)	22.5 ± 0	19.4 ± 1.3
June water depth (cm)	6.1 ± 0	14.9 ± 2.0
June plant submergence (%)	27.1 ± 0	78.3 ± 9.2
September water depth (cm)	0.1 ± 0	17.9 ± 1.8
September plant submergence (%)	0.4 ± 0	100.6 ± 13.1
Average water depth (cm)	3.1 ± 0	16.4 ± 1.8
Average plant submergence (%)	13.8 ± 0	89.5 ± 10.4

[a]"Dead" plants were those whose aboveground portions were present, but severely decomposed, or whose aboveground portions were entirely rotted off.

DISCUSSION

This study provides evidence that flooding on the Sheyenne National Grassland differentially affects vegetative and flowering western prairie fringed orchids. Seventy percent of the flowering orchids persisted through the 1993 growing season, compared to only 3% of the shorter vegetative plants. The low rate of persistence of vegetative plants was attributed to their short stature and absence of a hollow seed stalk. The greater height of flowering orchids and lower percentage of their total height that was submerged increased the odds that some portion of the plants was above the water and thus able to photosynthesize. Further, their hollow stems provided a likely conduit for oxygen to the roots. The development of pore space in the cortical tissues is an adaptation in wetland vascular plants that allows oxygen to diffuse from the aerial parts of the plant to the roots to supply root respiratory demands (Mitsch and Gosselink 1993).

For flowering plants, those that persisted through the 1993 growing season were taller and had a smaller percentage of their total height submerged. Our evidence (Wolken 1995) suggests that the western prairie fringed orchid is similar to species such as the little green orchid (*P. hyperborea*) (Currah et al. 1990) in that successful development of the mature plant, flowers, fruits and storage tissue depends on the photosynthetic gains of the new foliage (Pate and Dixon 1982). Present photosynthates also contribute to the formation of next season's shoot bud and immature root system (Currah et al. 1990). Taller flowering plants with a greater portion of their biomass above the water would be more likely to produce adequate photosynthates for completion of their seasonal development.

Yet, many orchids that did survive through 1993 failed to reappear in subsequent growing seasons. Only 13% of the flowering plants that survived through the 1993 growing season reappeared in 1994, and only one of these plants reappeared in 1995. Demographic data collected on the Sheyenne National Grassland between 1990 and 1994 indicated that the percentage of marked plants that reappeared the following year ranged from a high of 73% for the 1991 cohort to only 16% for the 1993 cohort (Sieg and King 1995). This variation in reappearance rates is likely influenced by environmental conditions both the first year and in subsequent years. The exposure to environmental stresses such as flooding may have a carry–over effect in subsequent growing seasons (Bowles et al. 1992, Falb and Leopold 1993, Lesica and Steele 1994). Environmental stresses or damage in a previous season during which carbohydrate reserves and perennating tissues were formed, or during the beginning of the current growing season when adequate conditions dictate the growth and survival of a new plant, were thought to be cues that influenced the reappearance of plants during a growing season (Epling and Lewis 1952, Stoutamire 1974, Pate and Dixon 1982, Davies et al. 1983, Mehrhoff 1989).

Another factor that certainly influences the survival of flooded plants is the timing and duration

Table 3. Presence the second growing season (1994) of 33 vegetative and 33 flowering western prairie fringed orchids occurring in flooded swales, by their status (alive or "dead"[a]) at the end of the growing season in 1993.

Life state	Status at end of 1993	n	Presence in 1994: Present (life state)[b]	Absent
Vegetative	alive	1	1 (V)	-
	"dead"	32	0	32
Flowering	alive	23	3 (2V, 1F)	20
	"dead"	10	0	10

[a]"Dead" plants were those whose aboveground portions were present, but severely decomposed, or whose aboveground portions were entirely rotted off.
[b]V = vegetative; F = flowering

of the flooding. In 1993, the swales remained flooded through the growing season, in response to high summer precipitation. In fact, the water depth increased through the growing season in many swales, and this was 1 of only 2 times that the flow in the Sheyenne River at Lisbon exceeded flood stage after May (2 August); the only other time this occurred since 1950 was on 1 July 1975 (National Weather Service unpublished data, on file at the National Weather Service Office, Grand Forks, ND 58203-0600). It is likely that plants would be more likely to persist, and flowering plants more likely to produce seeds, in years when the flooding occurs early in the growing season and then subsides.

For the plants whose aboveground portions perished, the question remains if the plants can survive belowground. Although the prairie fringed orchids, like many species of orchids, are known for their erratic dormancy patterns (e. g. Hutchings 1989), few data are available on the long-term impacts of flooding or other stresses on survival of individual plants. In an effort to assess if aboveground absence was due to dormancy or death, we excavated 10 orchids in 1994 that were present and precisely marked in 1993, and absent aboveground in 1994. We removed a 40-cm diameter by 20-cm deep plug of soil around the location of each absent orchid and carefully searched for any evidence of the 1993 dormant root system, and found no evidence of any recognizable root system tissue where any of the ten 1993 orchids were originally marked (Wolken 1995). Demographic data collected between 1987 and 1994 on the Sheyenne National Grassland indicate that once orchids disappear, the odds of reappearing above-ground the following year are < 20% (Sieg and King 1995). Therefore, it is unlikely that the plants that did not reappear in 1994 or in subsequent years will reappear aboveground in the future.

Although this paper documents that flooding has a detrimental effect on the persistence of some individual orchids occurring in the wettest portions of the landscape, we do not suggest that flooding over the last 4 years has destroyed the metapopulation of the western prairie fringed orchid on the Sheyenne National Grassland. To the contrary, we observed high numbers of orchids on the Grassland in 1993 and in subsequent years (Sieg and King 1995). However, we have documented a shift in the metapopulation. Swales that supported orchids during a drought in the early 1990's have been flooded and devoid of orchids since 1993; yet the presence of orchids on higher landscape positions have resulted in a net increase in orchid numbers on the National Grassland beginning in 1993 (Sieg and King 1995).

Although flooding may result in low persistence rates especially for vegetative plants, flooding also creates habitats with suitable moisture conditions higher on the landscape and then serves to disperse orchid seeds to these habitats. The dust-like seeds of orchids are among the smallest known in the plant kingdom; because of their minute size (from 0.07 to 0.4 mm across and from 0.11 to 1.97 mm in length), we know relatively little about their germination ecology (Rasmussen 1995). The minute size and inflated air-filled testa make orchid seeds well equipped for wind dispersal, but the water-repellent lipoid layer, buoyancy and rough surface enable them to float on the surface of water (Rasmussen 1995). Flooding functions to concentrate and deposit seeds of wetland plants along drift lines (Mitsch and Gosselink 1993).

Therefore, to appreciate the complete and complex role of flooding on the life history and distribution of the western prairie fringed orchid and other wetland species, data from both individual plant and landscape levels are needed. Floods and droughts are catastrophic events that play a significant role in both modifying yet perpetuating these wetland systems and their associated species (Mitsch and Gosselink 1993). Further, long-term data sets that incorporate the impacts of droughts, fires and human influences are needed to fully understand the population dynamics of this threatened plant species.

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EVALUATION OF WET MEADOW RESTORATIONS IN THE PLATTE RIVER VALLEY

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Abstract: The mission of the Platte River Whooping Crane Maintenance Trust is to protect and manage habitat in the Platte valley for whooping cranes (*Grus americana*), sandhill cranes (*Grus canadensis*), and other migratory birds. The plan for meeting this mission calls for the creation and maintenance of 11 habitat complexes distributed through the central Platte River valley. Each habitat complex is intended to consist of 1000 hectares of wet meadows and adjacent roost habitat of unvegetated river channel. Since approximately 75% of Platte valley wet meadows have been converted to crop land, there is not enough existing wet meadow habitat to meet the requirements of the habitat complex plan. Consequently, restoration of areas to wet meadow-type vegetation is necessary. Over the past 17 years, the Trust has attempted a variety of restoration techniques on 485 hectares of its lands. These restoration techniques fall into three basic categories: 1) low diversity (3-6 species) CRP-type grass plantings on former crop fields; 2) cleared riparian forests; and, most recently, 3) high diversity (100+ species) plantings on former crop fields, including land surface recontouring to create ridge and slough topography typical of native meadows. We are evaluating the restored areas to determine the relative success of the various techniques in creating vegetation that resembles the vegetation of native meadows. In spite of being done relatively recently (< 5 years) the high diversity plantings are already developing vegetation that more closely resembles native sites than either the low diversity plantings or the cleared forests, many of which are more than 10 years old. Based on these results, future restoration efforts should continue to focus on the high diversity technique.

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Key words: high diversity technique, migratory birds, river channel, sandhill cranes, Whooping Crane Maintenance Trust.

The "Big Bend" reach of the central Platte River valley (the 70-mile stretch from Overton to Chapman, Nebraska) has hemispherical significance as a staging area for migratory birds. The region is best known for the nearly 500,000 sandhill cranes (*Grus canadensis*) and several million ducks and geese that migrate annually through the region (Sidle et al. 1993). In total, approximately 300 species of birds use the woodlands, wet meadows, and river channel in the valley (Currier et al. 1985).

At the time of European settlement, the Platte River was characterized by having several wide braided channels with wet meadows adjacent to and between the channels. Trees were sparse and present as scattered clumps along some of the river banks. However, over the past century, the central Platte River valley has undergone a substantial transformation. Numerous dams and water diversions in Wyoming, Colorado, and western Nebraska have significantly reduced natural flows and sediment discharge. Peak discharge has declined nearly 70% and the river channel is only 10-70% of its 1865 width (O'Brien and Currier 1987). Once wide and treeless channels have been transformed to multiple, narrow channels with woody vegetation succeeding on stabilized sandbars (Sidle et al. 1989, MacDonald and Sidle 1992). Approximately 75% of native wet meadows associated with the river have been converted to crop land (Sidle et al. 1989).

The Platte River Whooping Crane Trust (the Trust) was created in 1979 with the mission of acquiring and protecting habitat for migratory birds, whooping cranes (*Grus americana*) in particular, in the central Platte valley. The habitat plan developed by the Trust calls for the protection of 1000 ha of habitat in each of the 11 bridge segments between Overton and Chapman. Land acquisition efforts have focused on river channel and native wet meadows, as these are limited in availability and are considered to be the most critical habitats for many species of migratory birds, including whooping cranes. However, in the process of buying these habitats, adjacent crop fields are often included. Consequently, crop land makes up 880 ha of the approximately 3,600 ha of land protected by the Trust to date. Many of these fields are marginally productive as crop land due to low fertility, high water tables, and/or high soil pH and are good candidates for wet meadow restoration. Additionally, in some bridge segments, there are not enough existing wet meadows to meet the habitat goals.

To increase the availability of wet meadow habitat for migratory birds, the Trust and other conservation groups have begun efforts to restore areas to wet meadow-type vegetation. A variety of techniques were used for these restorations.

The earliest technique consisted of planting crop fields to low diversity (3-6 species) mix of native warm season grasses, primarily big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans* [*avenaceum*]), and switchgrass (*Panicum virgatum*). These were CRP-type (USDA Conservation Reserve Program) plantings, and no effort was made to introduce forbs or enhance the hydrology of the sites.

Starting in the early 1990's, the Trust began restoring crop fields by planting high diversity (100-200) species seed mixtures using locally harvested seeds. In some of these fields, a bulldozer was used to recontour the land surface to enhance the hydrology of the sites and create slough and ridge topography resembling that of native meadows.

The third restoration technique employed by the Trust involved reclaiming riparian areas by clearing cottonwood forests adjacent to the river to allow the development of grassland vegetation. The forests developed on stabilized river channel over the past 50 years as a result of reduced flows in the river since the completion of Kingsley dam in western Nebraska. Clearing these forests offered the potential to create wet meadows in the topographic position they would have originally occupied. None of these sites was seeded. Cleared areas were simply allowed to re-vegetate on their own.

In order to ensure that future restorations come as close as possible to mimicking native meadows, we are evaluating the 3 techniques used to date. This paper represents the first systematic effort to evaluate the relative success of these techniques in creating vegetation that resembles the vegetation of native wet meadows. Preliminary analysis of the data is presented here.

METHODS

Study Areas

We chose 14 native wet meadow areas to serve as reference sites to compare to the restorations. The restorations were divided into 3 groups according to the techniques used to create them. There were 7 low diversity plantings, 11 high diversity plantings, and 4 reclaimed riparian sites. Permanent 200-m long transects were established on each site. Transects were set up so that they cut across the gradient of sloughs and ridges in each site and the proportion of slough, mesic prairie, and sand ridge areas were roughly equivalent in the native reference meadows and the restorations. Cover values were estimated at 10-m intervals along each transect using a 0.1-m^2 quadrat (Daubenmire 1959). Each transect was sampled in June 1997 and again in June 1998.

Data Analysis

For purposes of analysis, plant species were grouped into 8 categories: warm season native grasses, cool season native grasses, cool season exotic grasses, sedges & rushes, conservative prairie forbs (species that are present only on high quality native meadows and are very sensitive to management practices), other prairie forbs, wetland forbs, and exotic forbs (Table 1). Cover values of each category of each restoration technique were compared to the reference sites using ANOVA. Differences in means were examined with Student-Newman-Keuls Test at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Native Platte River wet meadows are characterized topographically by being relatively flat, but with series of sinuous, linear sloughs aligned roughly parallel to the river with adjacent areas of mesic prairie and/or sand ridges. Plant communities range from emergent aquatic vegetation in the bottoms of the deepest sloughs to Sandhills prairie on the highest ridges. Overall, reference meadows are dominated by warm season grasses and sedges & rushes. Cool season native grasses and conservative prairie forbs are relatively uncommon. Exotic species account for just over 10% of the vegetation on these sites. On average, a good quality native meadow will contain between 120 and 150 species of native plants.

Low Diversity Plantings

Compared to native reference meadows, low diversity plantings had significantly greater cover of exotic cool season grasses and exotic forbs and significantly less cover of sedges & rushes and wetland forbs (Table 2).

When the low diversity plantings were being done, it was hoped that many additional plant species would colonize the sites from adjacent native meadows. So far, it appears that only a few of the most aggressive species are capable of doing so, and some of these plantings are approaching 20 years old. Species richness of these sites remains very low with

Table 1. Vegetation categories and the most common species in each category. Names follow the Atlas of the Flora of the Great Plains (Barkley 1977).

Categories	Common Name	Scientific Name
Warm Season Native Grasses	big bluestem	*Andropogon gerardii*
	Indian grass	*Sorghastrum nutans (avenaceum)*
	switchgrass	*Panicum virgatum*
	prairie cordgrass	*Spartina pectinata*
	rice cutgrass	*Leersia orizoides*
Cool Season Native Grasses	slender wheatgrass	*Agropyron caninum*
	northern reedgrass	*Calamagrostis inexpansa*
	prairie wedgegrass	*Sphenopolis obtusata*
	Canada wild rye	*Elymus canadensis*
Cool Season Exotic Grasses	smooth brome	*Bromus inermis*
	redtop	*Agrostis stolonifera*
	Kentucky bluegrass	*Poa pratensis*
Sedges and Rushes	water sedge	*Carex aquatilis*
	broom sedge	*Carex scoparia*
	darkgreen bulrush	*Scirpus atrovirens*
	Torrey's rush	*Juncus torreyi*
	path rush	*Juncus tenuis*
Conservative Prairie Forbs	wholeleaf rosinweed	*Silphium integrifolium*
	purple prairie clover	*Petalostemum purpurea*
	Canada milkvetch	*Astragalus canadensis*
	tall blazingstar	*Liatris pycnostachya*
Other Prairie Forbs	white aster	*Aster ericoides*
	wild licorice	*Glycyrrhiza lepidota*
	black-eyed susan	*Rudbeckia hirta*
	pale-spike lobelia	*Lobelia spicata*
	prairie goldenrod	*Solidago missouriensis*
Wetland Forbs	boneset	*Eupatorium perfoliatum*
	sneezeweed	*Helenium autumnale*
	tufted loosestrife	*Lysimachia thyrsiflora*
	winged loosestrife	*Lythrum alatum*
	water parsnip	*Sium suave*
Exotic Forbs	white sweet clover	*Melilotus alba*
	curly dock	*Rumex crispus*
	red clover	*Trifolium pratense*

less than 30 species The low diversity plantings are also highly vulnerable to invasion by undesirable exotic plants, particularly smooth brome (*Bromus inermis*) and redtop (*Agrostis stolonifera*). This is most likely a result of the patchy nature of warm season grass plantings, which provides ample open space for the exotic grasses to exploit.

High Diversity Plantings

Compared to native reference meadows, the high diversity plantings had significantly greater cover of warm season native grasses, cool season native grasses and significantly less cover of sedges & rushes and wetland forbs (Table 2). Many of the sedges, rushes, and other wetland species are present in the restoration, but they occur in low numbers. They simply seem to develop at a much slower rate than the mesic prairie species. For example, broom sedge (*Carex scoparia*), an abundant species in native meadows that has been planted in many of the high

Table 2. Mean percent cover of vegetation categories. Similar letters indicate no significant difference (P>.05) between treatments.

Category	Native	High Divers.	Low Divers.	Riparian
Warm Season Grass	21.5a	33.9b	17.8a	16.0a
Cool Season Native	1.3a	8.3b	1.9a	1.9a
Cool Season Exotic	7.8a	2.0a	28.2b	8.3a
Sedges & Rushes	25.6a	4.9b	2.0b	21.1a
Conservative Forbs	1.0a	9.0b	2.0a	0.0a
Prairie Forbs	13.9a	18.7a	11.5a	11.3a
Wetland Forbs	5.6a	1.2b	0.6b	2.7ab
Exotic Forbs	3.1a	4.6a	12.5b	6.8a

diversity restorations, has never been observed in any of the sites prior to the third year after planting. Once it does appear, it increases steadily in abundance.

Many of the conservative prairie forbs have limited distributions and small populations in the Platte valley. They occur primarily on a handful sites that were not subject to abusive management practices in the past. The relative abundance of conservative prairie species in the high diversity restorations compared to native sites is simply the result of a concerted effort to harvest seed from these species with the intent of establishing new and larger populations of them.

Plant species richness of the high diversity sites is equivalent to that of the native reference meadows (120-150 species).

Reclaimed Riparian Areas

None of the vegetation categories in the riparian areas was significantly different in cover values from those of the reference sites (Table 2). However, species richness of these areas was very low (< 50 species) compared to either native meadows or high diversity restorations. What appears to have happened on these sites is that a few plant species typical of wet meadows (such as water sedge [*Carex aquatilis*], prairie cordgrass [*Spartina pectinata*], and tufted loosestrife [*Lysimachia thyrsiflora*]) were present as scattered patches within the woodlands. Once the overstory trees were removed, these plants rapidly expanded and now dominate the sites. Unlike native reference meadows, reclaimed riparian areas also have a high degree of shrub cover, primarily rough-leaved dogwood (*Cornus drummondii*) and false indigo [indigobush] (*Amorpha fruticosa*), that have proven difficult to control.

CONCLUSIONS

Preliminary analysis of the data collected in this study indicates the high diversity planting technique offers the best potential for wet meadow restorations. The high diversity restorations have been completed more recently, and have had less time to develop than either the low diversity plantings or the reclaimed riparian areas. In spite of that fact, the high diversity restorations have already developed vegetation that more closely resembles native wet meadows than either of the other to restoration types.

Reclaiming riparian areas by removing trees offers some potential as an acceptable wet meadow restoration technique if an effective means of controlling shrubs can be developed. However, it may be necessary to seed these areas once the trees are removed to improve the diversity of the wet meadow plant community that will eventually develop there.

The low diversity grass planting technique offers the least value for wet meadow restoration. This technique is not recommended for future wet meadow restorations in the Platte River valley.

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PRAIRIE AND WETLAND RESTORATION ALONG THE CENTRAL PLATTE RIVER, 1991-1998

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Abstract: In 1991, Prairie Plains Resource Institute began a Platte River grasslands ecological restoration project along the central Platte River. The major objectives of this project were to plant an increasing number of ac each year, beginning at approximately 15 ha (40 ac), locate and document wild sources of native plant seeds, develop effective harvesting and seed handling techniques, work on site-specific seedbed preparation techniques, create wetlands, and involve volunteers in the process of restoration. The project was supported by the U. S. Fish and Wildlife Service from 1991-1995, and since then by the U. S. Environmental Protection Agency Region VII, through UNL's Platte River Watershed Program. The majority of the restoration work has been done in cooperation with and on lands belonging to the Platte River Whooping Crane Maintenance Trust (Wood River, Nebraska), The Nature Conservancy (Platte River/Rainwater Basin Project Office, Aurora, Nebraska), and the U. S. Fish and Wildlife Service (Rainwater Basin Wetland Office, Kearney, Nebraska). All project objectives have been met to date. With assistance from more than 30 volunteers, approximately 315 ha (800 ac) of prairie and wetland have been planted with high-diversity grass and forb mixtures (minimum of 100 species per mix) and are being managed with various mowing, grazing, and burning schedules.

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Key words: Prairie Plains Resource Institute, seedbed preparation, seed handling techniques.

Much background about Prairie Plains Resource Institute (PPRI) and its pioneering role in prairie and wetland restoration in central Nebraska is included in a 2-part article by Whitney (1997). Additional how-to information (including a plant list of 140 species) on the PPRI restoration process can be garnered from Whitney (1998). The following paper is a general narrative of PPRI restoration work begun in 1991 which included, in addition to Platte Valley sites, a number of small plantings outside the valley, and a 63-ha (160-ac) Rainwater Basin restoration still in progress.

In the late 1970's, after visiting the historic restored prairies at the Morton Arboretum near Lyle, Illinois, and the University of Wisconsin—Madison Arboretum, I was impressed and intrigued by the concept of prairie restoration. Subsequently, I spent a great deal of time visiting a few widely scattered prairie remnants and native-vegetated roadsides in Hamilton and Merrick Counties, Nebraska, mostly along the Platte River. This enjoyable field work was instrumental in my learning about local prairie communities (xeric to wet) and in the collection of seeds from nearly 100 species to make a serious attempt at prairie restoration. Very small parcels of land to restore were available on property acquired by the fledgling PPRI (founded in 1980), but the task of high-diversity restoration seemed daunting at the time, even on 0.2-ha (0.5-ac) parcels.

The approach I used was to hand-collect at least a small amount of seeds from as many species as I could find that would be appropriate for the planting site. I mixed the seeds together and hand-broadcast onto various types of seedbeds ranging from earthmover-scraped areas to tilled ground. In my home greenhouse, I also learned basic propagation techniques for most of the species collected.

Successes followed most of my efforts during the early 1980's, yielding beautiful forby prairies by the end of the decade. As these early plantings evolved, I was excited by the possibilities of expanding the high-diversity concept beyond small areas; my sights became more focused on the potential of restoring prairies along the Platte River. In 1991, through a cooperative agreement between PPRI, the U. S. Fish and Wildlife Service, and the Platte River Whooping Crane Trust (then headquartered in Grand Island), the chance came to expand our restoration horizons. The first year's goals were as follows:

1. To locate and document wild native seed sources along the central Platte River.
2. To collect necessary phenological information on the plant species regarding seed collection.

3. To figure out ways to make seed collection and processing more efficient, including the creation of a small-scale harvesting machine.
4. To learn how to deal with challenges of handling and storing large quantities of seeds.
5. To experiment with various seed bed preparation and seed incorporation techniques.
6. To experiment with methods to enhance or create wetlands.
7. To plant approximately 15 ha (35-40 ac) of Platte River valley land.
8. To develop a volunteer program for collecting seeds and planting prairies.

At the beginning of the project, jumping from my accustomed 0.2-ha (0.5-ac) restorations to 15 ha (35 ac) involved considerably more effort, and was truly a leap of faith. But, my approach remained relatively unchanged from early restorations. Because I was uncertain about how much seed was enough when scattered over a large landscape, I tried to collect as much seed as possible. My annual seed collection list included (and still includes) at least 150 species, including dry sand ridge, mesic lowland tallgrass, and wet sedge meadow species.

Collection season the first year was continuous, so as not to miss anything, from the most obscure wet meadow sedge in June to the last aster late in the fall. Two important tool innovations helped. A simple tool for sedges was a hard plastic detergent jug made into a seed-raking collector. This was accomplished by cutting the lid off of the jug, then cutting teeth into the lip.

The second innovation was more complex. With the help of a creative and handy friend, we created a prototype reaper/harvester, complete with a vacuum conveyance and collection system. The first-year prototype was mounted onto the side of the pick-up truck. This prototype was later adapted to fit onto a Grasshopper™ lawn mower power unit. The machine allowed hydrostatic drive maneuverability, adjustable cutting heights from about 0.2-1.5 m (8 in to 5 ft), and it had a large bin to hold the clippings. It could be trailered behind a pickup and operated by 1 person.

This seed harvester was in use for 3 collection seasons and accomplished the harvesting of enough tallgrass seed and a number of fall-collected forbs to plant more than 39 ha (100 ac). Later, tallgrass harvesting was done with a 1960's vintage Allis-Chalmers™ combine owned by the Platte River Whooping Crane Maintenance Trust. The small-scale harvester concept worked well, but additional design and fabrication engineering is needed to perfect the concept.

I stored many forb seeds in 1-gal (4-L) plastic milk jugs. Large quantities of hand-collected grasses such as prairie wedgegrass (*Sphenophilis obtusata*) or Canada wild rye (*Elymus canadensis*) were stored either in 5-gal (20-L) plastic buckets or in large, inexpensive, plastic garbage barrels. The 5-gal buckets are invaluable vessels for seed collecting and planting, and can often be obtained for free from bakeries or construction sites. The lids of the large barrels are valuable as trays during the seed drying and processing stages.

Most collected material was processed by forcing it through fanning mill screens. This broke seed heads apart and separated seeds from stem, etc. After processing, the seeds were mixed together by general plant community types of sand ridge, mesic tallgrass, and wetland mixes. Bulk quantities of the tall dominant grasses are kept separate from the forb and hand-collected grass mixes. The dominant grasses require large protected spaces for winter storage.

To test wetland and dry upland seed mixes, I used a small earth mover to sculpt a long drainage and wetland pool into the first restoration site (Uridil #1 in Table 1), creating a spoil pile alongside the depression that simulated natural ridge topography. The 0.3-m (1-ft) depth relief of the artificially-created depression collected precipitation draining off the field and emptied into a more deeply excavated (1.0- to 1.5-m) standing water pool (dug below the level of the groundwater). The spoil ridge contained a high proportion of sand in order to favor development of an upland plant community.

That first year, I spent little time worrying about the actual seeding. When the time came to plant in spring 1992, I located 3 people to help sow seeds by hand. We improvised a sowing method (still used on most new plantings) of flagging the corners of a 0.4–ha plot (1.0–ac) of ground, then walking in pairs: 1 person sowing forb mix and another with the bulk grass mix, going back and forth across the area in 5- to 6-m swaths. Progress down the field is marked on both sides of the planting unit by strategically placing flags that the sowers can always aim towards. (A 0.4-ha plot is a large space to someone on foot. Without flagging, it would be easy to lose track of what has been planted and what has not.)

The forb mix in all plantings to date contains hand-collected grass seed as well as thousands of small, fluffy, and heavy forb seeds. The forb mix bulk is dominated by the large fluffy seeds of Canada

Table 1. A chronological listing of sites restored by the Prairie Plains Resource Institute in Nebraska, 1991-1998. Sites not in the Platte River valley are marked by an asterisk (*).

Tract Name	Planted	Location	Size	History	Comments
Uridil #1 (PRWC Maintenance Trust[a])	20 May 1992	Hall Co., 6.4 km (4 mi) SW of I-80 Exit 300 (Wood River exit)	13.8 ha (35 ac)	irrigated corn and milo, broken in 1970s, leveled for gravity irrigation, approx. 3-4 ha (8-10 ac) are prone to spring inundation due to high water in an adjacent stream	includes creation of a wetland; hand-broadcast, seed was hand-collected and harvested by prototype harvesting machine, see RMN10(1):5; culti-packed for seed incorporation, mowed in year 1
* **The Leadership Center** (NE Voc. Ag. Fnd.)	23 June 1992	Hamilton Co., east edge of Aurora, 4.8 km (3 mi) N of I-80 Exit 332	0.4 ha (1 ac)	a level Lincoln Creek lowland milo field, deep silt-loam soil	hand-broadcast and culti-packed, some commercial grass seed included, mowed in year 1
West Ruge (PRWC Maintenance Trust)	29 Apr 1993	Hall Co., 1.6 km (1 mi) NE of I-80 Exit 305 (Alda exit)	5.1 ha (13 ac)	a level lowland bean and milo field; no major slough features but can be inundated on rare occasion by an adjacent stream	hand-broadcast, seed was harvested by hand and the upgraded mower-mounted harvester, mowed in year 1
Robinson (PRWC Maintenance Trust)	23 May 1993	Phelps Co., 11.2 km (7 mi) SW of I-80 Exit 257 (Elm Creek exit)	15.7 ha (40 ac)	a level field with row-crop farming history; too far above water table to have wet surface features	tall grasses planted with E-Z Flow fertilizer spreader; forbs spread by volunteer riding on the spreader; culti-packed for seed incorporation.
Stuhr Museum	24 May 1993	Hall Co., 4.8 km (3 mi) N of I-80 Exit 312 (Grand Island/Hastings exit)	2.8 ha (7 ac)	a level dryland cornfield, sandy loam soil, no wet surface topography	hand-broadcast and culti-packed, museum added some commercial grass seed, unmowed in year 1
Morse (PRWC Maintenance Trust)	27 May 1993	Phelps Co., 11.2 km (7 mi) SW of I-80 Exit 257 (Elm Creek exit)	23.6 ha (60 ac)	level field with row-cropping history; no wet surface features	had been sown with a grass drill and purchased seeds of major tall grasses; we hand-broadcast a mix of forbs and non-dominant grass species, mowed in year 1
* **The Leadership Center** (NE Voc. Ag. Fnd.)	8 June 1993	Hamilton Co., east edge of Aurora, 4.8 km (3 mi) N of I-80, Exit 332	0.4 ha (1 ac)	a level dryland Lincoln Creek lowland terrace milo field, deep silt-loam soil	hand-broadcast and culti-packed, some commercial grass seed included, mowed in year 1
Dahms pivot (Nature Conservancy)	23 April 1994	Hall Co., 1.6 km (1 mi) S of I-80 Exit 300 (Wood River exit)	41.3 ha (105 ac)	included deepening an existing slough; a pivot-irrigated cornfield; native prairie broken in 70's; slough drainage topography still present; tract flooded extensively 2 of last 3 years	27.6 ha (70 ac) drilled by Truax drill with 5 species of commercial tall grasses; volunteer hand-broadcast 7 plots totaling 13.8 ha (35 ac) with high-diversity species mix, unmowed in year 1

Table 1. (Continued)

Tract Name	Planted	Location	Size	History	Comments
Dahms set-aside (Nature Conservancy)	23 April 1994	adjacent to Dahms Pivot above	3.1 ha (8 ac)	a tag-end piece of non-irrigated cropland, very low and often partially inundated during the spring, with wet alkali-encrusted soils	hand-broadcast, culti-packed to incorporate seeds into soil. unmowed in year 1
Trust Pits (PRWC Maintenance Trust)	5 May 1994	3.2 km (2 mi) SE of I-80 Exit 305 (Alda exit)	3.1 ha (8 ac)	the periphery of a gravel-mining lake (sandpits); the Trust dozed in the banks to make sections of the pits into a shallow wetland	hand-broadcast, culti-packed to incorporate seeds, unmowed in year 1
Caraway (Platte River Trust)	12 May 1994	Hall Co., 6.4 km (4 mi) NW of I-80 Exit 318 (Phillips/Grand Island Exit)	19.7 ha (50 ac)	a rolling loess site (the lowland prairies of the level Platte Valley grade upward some 15 meters to a loess plain	Planted with an EZ-flow fertilizer spreader after disking; culti-packed to incorporate seeds; this site would support an upland tallgrass prairie community, mowed in year 1
*** The Leadership Center** (NE Voc. Ag. Fnd.)	12 June 1994	Hamilton Co., east edge of Aurora, 4.8 km (3 mi) N of I-80, Exit 332 (Aurora Exit)	0.8 ha (2 ac)	a level dryland Lincoln Creek lowland terrace milo field, deep silt-loam soil	hand-broadcast and harrowed, mowed one in mid-summer
Dahms East (Nature Conservancy)	15 April 1995	Hall Co., 3.2 km (2 mi) S of I-80 Exit 300 (Wood River exit)	16.9 ha (43 ac)	a leveled, gravity-irrigated cornfield; 2-3 ha may occasionally become inundated on east eand during floods	hand-broadcast, no culti-packing, unmowed in year 1
Studnicka Buffer Strip (Nature Conservancy)	22 April 1995	Hall Co., SW of South Channel Bridge 4.8 km (3 mi) S of I-80 exit 305 (Alda Exit)	2 ha (5 ac)	had most recently been a cornfield; level and adjacent to main Platte channel; with a high water table and inundated during extremely high river flows (1995)	hand-broadcast; no culti-packing, unmowed in year 1
Uridil #2 (PRWC Maintenance Trust)	22 May 1995	Hall Co., 6.4 km (4 mi) SW of I-80 Exit 300 (Wood River exit)	19.7 ha (50 ac)	immediately north and similar to Uridil #1	includes a large-scale wetland creation; grasses planted by EZ-Flow fertilizer spreader; forbs spread by hand seeding out the rear tractor cab window, unmowed in year 1
Moeller Bean Field (PRWC Maintenance Trust)	6 June 1995	Hall Co., 2.4 km (1.5 mi) S of I-80 Exit 312 (Grand Island/Hastings Exit)	3.1 ha (8 ac)	a dryland farmed soybean filed occasionall inundated and with a high groundwater level despite lack of wet slough surface features	grasses planted by EZ-Flow fertilizer spreader pulling a harro; forbs spread by hand seeding out the rear tractor cab window, unmowed in year 1

Table 1. (Continued)

Tract Name	Planted	Location	Size	History	Comments
Stuhr Museum Wetland	17 May 1995	Hall Co., 4.8 km (3 mi) N of I-80 Exit 312 (Grand Island/Hastings exit)	1.2 ha (3 ac)	dozer-dug hole with sandy spoil mounds	was not planted in its first year, weedy by second, hand-broadcast
* **The Leadership Center** (NE Voc. Ag. Fnd.)	25 May 1995	Hamilton Co., E edge of Aurora, 4.8 km (3 mi) N of I-80, Exit 332 (Aurora Exit)	1.2 ha (3 ac)	a level dryland Lincoln Creek lowland terrace milo field, deep silt-loam soil	hand-broadcast and left alone
Johns (PRWC Maintenance Trust)	16 June 1995	Buffalo CO. NE, 8 km (5 mi) SE of I-80 Exit 257 (Elm Creek Exit)	3.1 ha (8 ac)	a part-sandy, part-lowland dryland crop field	grasses planted by EZ-Flow fertilizer spreader; forbs spread by hand seeding out the rear tractor cab window
Studnicka Wetland (Nature Conservancy)	13 April 1996	Hall Co., SW of South Channel Bridge 4.8 km (3 mi) S of I-80 exit 305 (Alda Exit)	5.9 ha (15 ac)	a historic slough, once straightened into a ditch, then reconfigured by dozer into a serpentine slough and sand ridges	hand-broadcast low areas and ridges with high-diversity mix of species, unmowed in year 1
Dahms East #2 (Nature Conservancy)	April 1997	Hall Co., 3.2 km (2 mi) S of I-80 Exit 300 (Wood River exit)	18.5 (47 ac)	2 parcels including sandy and alkali sites, level dryland crop field (usually corn)	hand-broadcast, no seed incorporation
Dahms South Drainage (Nature Conservancy)	April 1997	Hall Co., 3.2 km (2 mi) S of I-80 Exit 300 (Wood River exit)	1 ha (2.5 ac)	a dozed drainage system designed to alleviate water acumulation on a neighbor's crop field; courses through a native meadow and connects to existing drainage topography there	hand-broadcast
Anderson (Nature Conservancy)	April 1997	Phelps Co., 11.2 km (7 mi) SW of I-80 Exit 257 (Elm Creek exit)	11.8 ha (30 ac)	a level cornfield	hand-broadcast, no mowing first year
* **Springer Basin #1** (U. S. Fish and Wildlife Service)	April 1997	Hamilton Co., 3.2 km (2 mi) NE of I-80 Exit 325 (Giltner Exit)	9.8 ha (25 ac)	level soybean field, silty and well-drained; south end of Moeller Quarter	hand-broadcast, no incorporation, mowed in July of year 1

Table 1. (Continued)

Tract Name	Planted	Location	Size	History	Comments
* **Springer Basin #2** (U. S. Fish and Wildlife Service)	May 1997	Hamilton Co., 3.2 km (2 mi) NE of I-80 Exit 325 (Giltner Exit)	7.9 ha (20 ac)	hydric soils, north end of Moeller quarter	a thin hand-broadcast seeding with mesic and wetland species
* **Springer Basin #3** (U. S. Fish and Wildlife Service)	4 April 1998	Hamilton Co., 3.2 km (2 mi) NE of I-80 Exit 325 (Giltner Exit)	13.8 ha (35 ac)	soybean field, well-drained silty soils	hand-broadcast volunteer seeding by UNL and UNK wildlife clubs, no mowing in year 1
* **Springer Basin #4** (U. S. Fish and Wildlife Service)	25 April 1998	Hamilton Co., 3.2 km (2 mi) NE of I-80 Exit 325 (Giltner Exit)	10 ha (25 ac)	sown into 2nd-year oldfield in near-hydric soils on the north half of Moeller quarter	hand-broadcast, no seed incorporation, no mowing in year 1
Pawnee Hill/ Dexter Farm (private)	May 1998	Polk Co., along Highway 92 S of Clarks Platte River Bridge	2.8 ha (7 ac)	sown into overgrazed sod sprayed with roundup and 2,4-d for bluegrass and musk thistle control	hand broadcast, no incorporation, no mowing in year 1
Speidell Corn Tract #1 (Nature Conservancy)	May 1998	Buffalo Co., 6.4 km (4 mi) SW of I-80 Exit 279 (Minden Exit)	10 ha (25 ac)	a cornfield modified with dozer for wetland creation	hand-broadcast, no incorporation, no mowing in year 1
Speidell Trees (Nature Conservancy)	May 1998	Buffalo Co., 6.4 km (4 mi) SW of I-80 Exit 279 (Minden Exit)	7.9 ha (20 ac)	cedar tree removal area	hand-broadcast into slash and openings
Dahms South Pasture (Nature Conservancy)	May 1998	Hall Co., 4.8 km (3 mi) S of I-80 Exit 300 (Wood River exit)	39.4 ha (100 ac)	a pasture overseeding after early graze	hand-broadcast from a pickup box

[a] PRWC Maintenance Trust = Platte River Whooping Crane Maintenance Trust.

wild rye. Approximately 1.5 to 2 gal (< half a 20-L bucket full) of the forb mix is broadcast on a 0.4-ha (1.0-ac) plot. Standard application rates of the combine-harvested tallgrass species are 2.5 to 3 full buckets. For the first planting in 1991, we broadcast 3 buckets of grass seed, however the small prototype harvester collected much more straw and chaff. The 1992 and 1993 plantings were actually much lighter in seeding than subsequent seedings using a much cleaner mix harvested by the combine.

The seeds of the first planting were incorporated into the ground with a culti-packer implement fashioned from an old road roller and rotary harrow attachments.

The Uridil #1 site developed well despite trying conditions. It was the testing ground for new ideas, and I was under the scrutiny of project cooperators. Early on, I was not sure we had planted enough grass seed, and first-year weed growth was enormous on some parts. However, things looked good at the end of the first growing season; I could see many species with good populations.

As I was enjoying the sight of many forbs and grasses early in the summer of 1993 (and basking in the success a bit) the infamous rainy July of 1993 came along. Floods along the Platte River were not as extreme as the Mississippi River floods, but there was high water. Flooding in the South Channel adjacent to the Uridil #1 site inundated nearly a third of the planting for 2 to 3 weeks time. It killed the mesic vegetation that looked so good up to that time, but there were wetland species in the mesic tallgrass mix, such as cordgrass (*Spartina pectinata*) that benefited. The flood was a real lesson in stochastic events and restoration planning (i.e. know the site's hydrology!).

The plant community of the restoration was rapidly changed, and thereafter defined by the occurrence of an extreme disastrous event. The good news of the flood was in the fact that it proved 1 of the values of high-diversity restoration: ecological resilience due to diversity. There are species in the system that will benefit from extreme events. The native community will survive.

Weariness caused by the first large-scale hand-planting was a sure indication we needed more volunteers, or at least some mechanical assistance, when sowing large areas. But as the first planting progressed, it quickly became clear that the method itself worked well. This and subsequent volunteer plantings verify that hand-broadcast prairies develop uniformly and without the straight rows caused from seeding with a grass drill. Volunteers broadcast more than 40 ha (100 ac) per year presently. The forbs are widely and evenly dispersed, a situation that would be unlikely in a grass drill with settings optimized for a few select sizes and weights of seeds. Many small and heavy seeds would drop through the drill too quickly.

For mechanical assistance on some sites, I was able to use a tractor-pulled EZ-Flow™ granular fertilizer spreader (like a yard turf spreader, but about 4 m wide and pulled by a tractor) to seed grasses. When sowing with the EZ-Flow™, the forb mix was hand-broadcast through the rear window of the tractor cab. The EZ-Flow™ dropped an even stream of seeds onto the ground in rows about 0.2 m (8 in) apart. Since the seeds were not incorporated into the soil as they are in a grass drill, the winds and rains move them around a bit. The result is a random-looking planting, also without the row appearance of a grass-drilled planting.

The wetland planting of Uridil #1 was quite successful, even though many important wetland species appeared to be slower in developing and did not fill in as quickly as the prairie species of loamy mesic tallgrass sites. Perhaps this was due to the sterile sandy substrate left by the excavation process of wetland creation. The results of this 1992 experiment warranted further experimentation of this wetland creation method.

From the first year's planting, this restoration project subsequently grew to a 24-ha (60-ac) goal the second year. Then it grew to over 40 ha (100 ac) per year in ensuing years. It also included working with The Nature Conservancy (TNC) and with U. S. Fish and Wildlife Service on a 63-ha (160-ac) Rainwater Basin property. It could be argued that the Rainwater Basin wetland district south of the Platte River in central Nebraska is part of the Platte ecosystem. These wetlands, along with the river, are critical to large populations of Central Flyway waterfowl.

Table 1 contains a complete listing of all project plantings. Total restoration acreage is approximately 315 ha (800 ac) on 33 separate plantings. Six wetland sites are also included, a few of which expanded greatly on the original wetland dig idea tested on Uridil #1. On the Platte River Whooping Crane Maintenance Trust's Uridil #2 (adjoining Uridil #1 to the north) a much larger wetland was excavated to groundwater. On TNC's Studnicka property, a straight drainage was converted to a serpentine system containing numerous pools and ridges. And on TNC's Speidell tract, a 1998 wetland excavation created a spacious complex of drainage depressions and pools over a 10-ha (25-ac) site.

In addition to the large sites are a number of small ones such as at the Leadership Center in Aurora, and at the Stuhr Museum in Grand Island. It is my policy to continue planting small sites whenever the opportunity arises. These act as additional seed collection sites, they expose more people to prairie and restoration, and they are each an additional "field laboratory" for new techniques or different field conditions.

As of this writing, the annual seed collection and planting cycle is aimed at restoring between 60 and 80 ha (150 and 200 ac) in a given year. Many more marginal agricultural lands are slated to be restored in the future. Also, many low-diversity pastures will be overseeded in an attempt to increase their forb diversity. With the increases in planted acreages, it became desirable to minimize the time and equipment input on new plantings. Therefore, most new plantings are now done without seed incorporation or first year mowing of undesirable plant growth.

From meager and unproven beginnings, to the point where high-diversity restoration and wetland creation is becoming a standard procedure, the PPRI restoration process has changed little. **The key is to know the plants.** This emphatic statement implies that one must know where the plants are located, know the species in all seasons and all growth forms, and with respect to their community types, soils, and hydrologic requirements. From this knowledge the training of people for collecting the seed, processing and planting is straightforward.

The actual process of seed collecting, handling and planting is essentially a horticultural or an agricultural pursuit. As a restorationist, I take seeds from 1 place and put them onto another. Following an agricultural model, restorationists often strive in their projects to control nature in order to favor production targets. We cannot control many variables, so there is a tendency to develop strong notions about the few things that can be controlled. For example, just as in modern agricultural production, we strive for large-scale and high-efficiency accomplishments aided by mechanical and chemical technology. This is true for the processes of seed harvesting, planting, and control of undesirable plants (weeds!).

While it is practical and highly desirable to continue working on efficiency measures and new technology for restoration, such as I have done on this project, this should not prevent us from looking at other ways to do things. In addition, attention to the mechanics of restoration should not conflict with or detract from our seeing the greater ecological picture.

I prefer to include people in the restoration process over equipment whenever possible. If people participate, the results are usually excellent, more people are exposed to prairie and gain new knowledge about the process of restoration or management of grasslands, and volunteers can accomplish a great deal of work in a short amount of time. To plant with neophyte volunteers walking helter-skelter over a large field is anything but efficient or precise; but it works. More often than not, it is an enjoyable experience for the volunteers and it helps accomplish conservation and education objectives for restorationists.

I enjoy the horticultural and agricultural aspects of a restoration project, technological and otherwise. However, I do not think of the restoration as a static entity, or product, such as a field of beans. The ecological science of restoration (apart from the fundamental application of ecological knowledge related to the species collected, hydrology, etc.) is in testing and investigating our ideas about grassland ecology. By observing and studying the evolution of a restoration from a weed patch to a complex community, and by watching this evolution relative to the management practices we apply, we can gain valuable ecological insights.

During these 8 years of Platte River work, my own ecological perceptions pertaining to restoration and management has changed considerably. Like everyone else, I once viewed weeds in the early stages of a planting as a serious problem. I have seen extremely weedy restorations of cropland in which I could find none to few native seedlings in the first 2 years (and I know seedlings well). But the planting amazingly develops into prairie within about 5 years.

I have also had good luck with what is termed successional restoration (Packard 1994), whereby seeds are broadcast into an abandoned crop field, or oldfield, with dense weeds already established as the major vegetation. I have found that the succession of weedy species, native and non-native, is an interesting process. Species change each year, and subsequently many of the structural and spatial characteristics of the landscape also change dramatically. The progression keeps shifting until native grasses and forbs dominate and fire can be introduced into the system.

When a native perennial prairie system is fully established on all project sites, an active management will be initiated. Such management includes fire and grazing of various intensities, duration, and timings. This process has already begun on a few older sites.

The post-establishment monitoring and management phase of many of the Platte restorations is just beginning (Pfeiffer 1999), and could offer many new insights into how these restorations change. Also, much more scientific study is needed on the restorations regarding plant/insect interactions, wildlife use, grazing, and fire to name but few areas of interest.

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RESPONSE OF WETLAND PLANTS TO GROUNDWATER DEPTH ON THE MIDDLE LOUP RIVER, NEBRASKA

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Abstract: The main objective of this research was to try to define the wetland species preference for groundwater depth under field conditions. The Middle Loup River seemed ideally suited for such a project, since the amount of flow in this river does not fluctuate much during a typical year. The Loup River is exceptionally rich floristically, supporting well over 500 species of vascular plants. The flood plain appears to be nearly flat, but the 10- to 20-cm high terraces support different plant species than found at other elevations. This was assumed to be due to differing competitive abilities with different water depths. We took 147 1.0-m^2 quadrats along the Middle Loup River. In these quadrats, 102 species made up at least 0.1% composition. These species were analyzed for response to water depth. Correlation analysis did not show strong relationships of plant species with water table depth (most had $r < 0.20$). Sorting the species by water table depth proved to be more informative. Species response was compared with the classification of Reed, whose system is used in defining wetlands, in part. Most plant species agreed well with the Reed classification, but there were some species that did not. Water content, soil texture (especially grade of sand), penetrometer readings, and organic matter content all varied with depth to water table. These variables probably confound the effect of water table depth upon plant distribution.

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Key words: organic matter content, penetrometer readings, Reed classification, soil texture, water table depth.

Interest in wetland ecosystems has increased during the past decade. The Loup River wetlands have not been studied to any extent. The Loup Rivers (North, Middle and South) all originate in the Sandhills of Nebraska and are spring-fed. Precipitation has little effect on flow in these rivers; therefore, they have fairly constant flow throughout the year, compared the most plains rivers.

The low variation of flow makes the Loup Rivers a good location to study the effect of water table depth on wetland plant species. Here, the plants are subjected to about the same degree of inundation throughout the year as contrasted with the typical plains river wetland. There, the plant may be inundated in spring, but the water table may drop to 1 m below the surface or deeper by end-of-growing-season.

Little quantitative data have been published on depth to ground water as it relates to plant species distribution and abundance. This would seem to be a more definite measurement of a plant's wetland status than the system developed by the U. S. Fish and Wildlife Service (Reed 1988).

The main objective of this research was to determine the relationship between the plant composition and depth to groundwater. Secondary objectives were to relate plant composition to other physical factors such as organic matter, soil texture and compaction.

METHODS

This study was conducted on wet meadows and other riparian prairie types located along the Middle Loup and Loup Rivers in central Nebraska (Fig.1). Selection of study sites involved verifying that the site was composed of native vegetation (or at least not been cultivated for 50 years or more). We also selected areas that were at least in good or excellent condition due to excellent management

We established transects across each site selected for study, which included a variety of habitats located on the meadow. Global Positioning System (GPS) readings were taken at the head and tail of each transect, and linear distance between sampling sites was measured.

We took 1.0-m^2 quadrats along this transect wherever there was a change in elevation or vegetation. Elevation at each quadrat was determined relative to the river level with a Topcon™ laser survey instrument. A minimum of 5 quadrats was

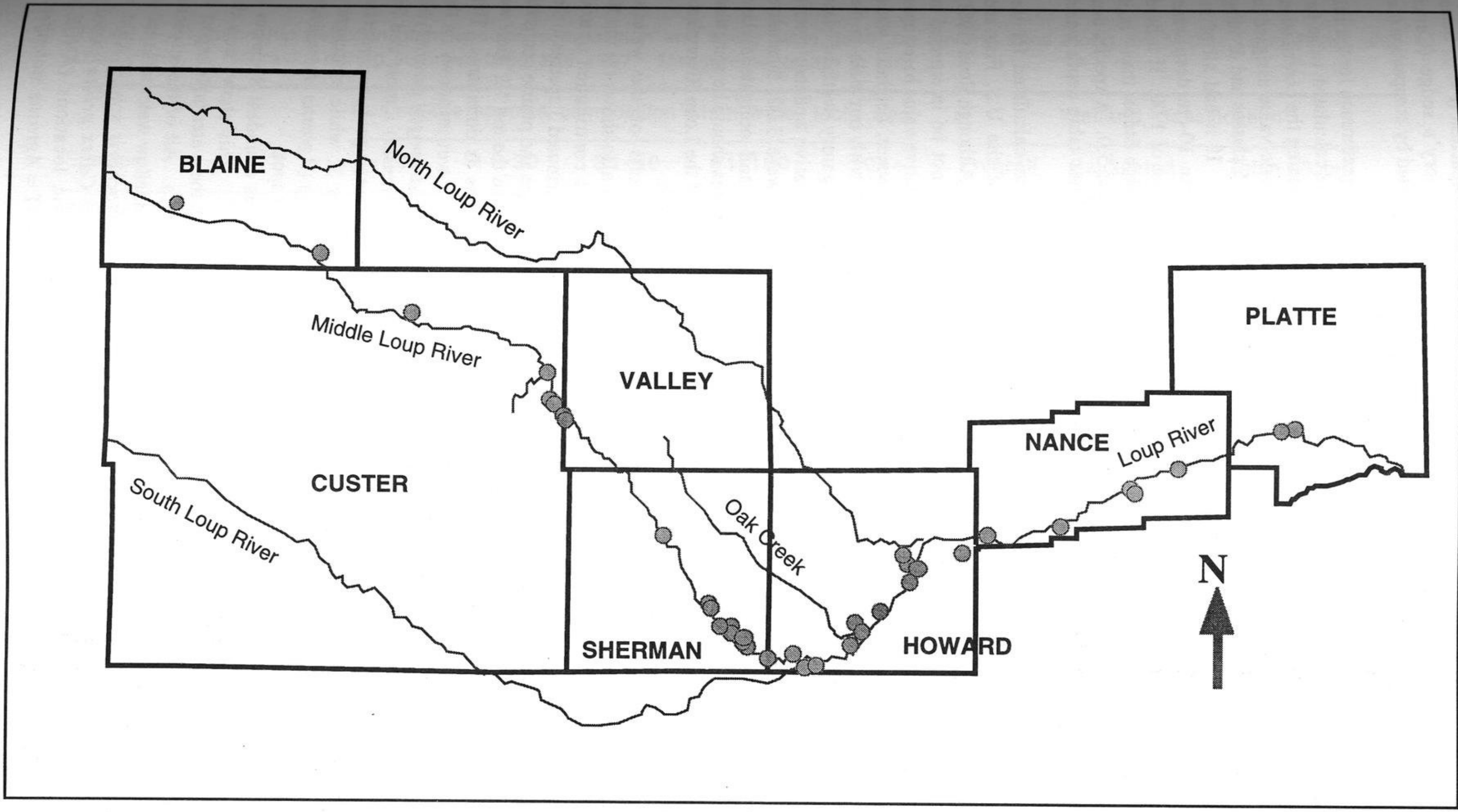

Fig. 1. Survey sites for 1996 through 1997 along the Middle Loup River, South Loup River and Loup River in central Nebraska.

taken at each of 26 sites during summer 1996 (Fig. 1). A 6.4-cm^2 diameter core was taken from the center of the round quadrat to a depth of 60 cm.

Organic matter was determined by the combustion method (Carter 1993).

Cone penetrometer readings were taken at 3 locations around the quadrat with a Dicky-John™ penetrometer (1.25-cm diameter cone, 7.6 cm between readings). Surface moisture levels were determined by resistance probes at depths of 3 inches and 6 inches (7.6 cm and 15.2 cm). If the water table was not encountered in the 60-cm deep hole, the hole was deepened with a sand bit. We dug until we hit water, unless the water was lower than 5 m. After hitting water, we dug about 10 cm deeper. We then allowed the water to stand 20 minutes before measuring the depth from the soil surface.

Soil series and range sites were determined at each quadrat location using soil survey manuals for each county. Plant names followed the Great Plains Floral Association (Barkley et al. 1986). At each quadrat, 2 to 4 botanists estimated vegetation composition, based upon amount of foliage of each species found. Consensus was reached before moving to the next quadrat. We read 147 quadrats during summer 1996.

RESULTS AND DISCUSSION

Over 500 species of vascular plants were identified in the Loup River and Middle Loup River riparian ecosystems in 1996 and 1997 (Rothenberger et al. 1998): 168 species were encountered in the 147 quadrats, and 102 species were deemed important (making up over 0.1% composition). These species are shown in Table 1. Species composition is also given for the 5 categories of water table depths and overall composition. Water tables were generally shallow, but at some locations were over 6 m deep.

There were 7 range sites represented on the study sites: wetlands, wet subirrigated, subirrigated, sands, sandy, sandy lowland, and silty. The depth to water was not level across the floodplain.

Soil organic matter ranged from less than 1% to over 8% by weight. Moisture content was quite wet except for sands and sandy sites, which frequently gave readings described as bone dry. Penetrometer readings varied greatly also, with uniformly low readings on sandy but with very high readings on silty.

Plant species showed little response to either organic matter or compaction (as measured by the penetrometer) in a correlation analysis (Table 2). Spikesedge (*Eleocharis*) was significantly affected by organic matter (r = +), and compaction (r = -). Some sedge species, especially Emory's sedge (*Carex emoryi*) were significantly affected by compaction (r = -) and by soil moisture (r = -).

We calculated water table preference for the 102 species shown in Table 1. The calculated value for each species was done by summing the contribution to composition times the numeric value assigned to the water table depth across all 5 classes and dividing the by the total composition. If it had all of its growth on areas with less than 10-cm deep water table, it would be given a value of 1.00. If it lived entirely on sites with a water table deeper than 1 m, it would be given a coefficient of 5.0. A species that showed no preference for water table depth would receive a value of 2.5.

Numeric values were also calculated for the wetland scoring procedure of the U.S. Fish and Wildlife Service (Reed 1988). Although Reed (1988) cautioned that "this index is not be interpreted as depth to water, etc., but is a relative value based upon duration of exposure to high water, height of water table, etc.," we compared it with our data in the following manner. An obligatory wetland plant species was scored 1.00; facultative wetlands species scored 2.00; mesic species were 3.00; facultative dryland species were 4.00; and obligate dryland species were 5.00. These scores should be somewhat comparable with the scoring of the Loup River plants based on actual place of growth.

Table 1 shows the results of the wetness indicators discussed above. It also shows the top 10 species of plants as far as its contribution to total biomass. Sedges (*Carex*) contributed 3 species to the top 10. In addition, spikesedge and prairie cordgrass (*Spartina pectinata*) also made the top 10. Here we have 5 native wetland species as dominants. This indicated the quality of these wet meadows on the Loup River. Big bluestem (*Andropogon gerardii*) and Kentucky bluegrass (*Poa pratensis*) almost tied for most contribution to biomass, prairie cordgrass followed closely for number 3, while switchgrass (*Panicum virgatum*) and redtop (*Agrostis stolonifera*). vied closely for the number 4 spot.

The response of the most abundant 8 species is shown graphically in Fig. 2. This shows how the dominant species divided up the water table aspect of the habitat among themselves. All of these species had preferences either at the shallow water table end of the gradient (ELEO = *Eleocharis* spp., CAEM = *Carex emoryi*, and CAPE = *Carex pellita* [woolly sedge]), or the more mesic locations (ANGE = *Andropogon gerardii*, AGST = *Agrostis stolonifera*,

Table 1. Relationship between plant species composition and water table depth on several sites along the Middle Loup River, and Loup River, in Nebraska during summer 1996 and 1997. Measurements are in cm.

	Percentage species composition when water table was:					Wetland classification		
Species	0-10	11-30	31-60	61-100	101+	Overall	Calculated	Table (Reed)
Achillea millefolium	0.00	0.00	0.00	0.14	0.63	0.26	4.1	4.0
Agropyron intermedium	0.00	0.00	0.00	0.05	0.12	0.10	4.7	* *
Agrostis stolonifera	5.10	6.60	5.00	3.80	3.60	6.20	2.8	3.5
Ambrosia psilostachya	0.00	0.00	0.50	0.10	0.60	0.30	4.9	3.0
Amorpha canescens	0.00	0.00	0.00	0.00	0.90	0.30	5.0	* *
Amorpha fruticosa	0.50	0.00	0.00	0.00	0.00	0.10	1.0	1.0
Andropogon gerardii	0.70	0.60	5.40	4.00	25.30	9.90	4.5	2.5
Andropogon scoparius	0.00	0.00	0.00	1.00	3.50	1.60	4.8	* *
Antennaria neglecta	0.00	0.00	0.00	0.00	0.40	0.10	5.0	* *
Apocynum cannabinum	1.30	0.50	0.80	0.40	0.20	0.70	2.3	3.0
Artemisia ludoviciana	0.00	0.00	0.00	0.00	1.20	0.30	5.0	2.5
Aster ericoides	0.00	0.00	0.20	0.00	1.00	0.30	4.7	3.0
Boehmeria cylindrica	0.00	1.00	0.00	0.00	0.00	0.20	2.0	1.0
Bromus inermis	0.00	1.00	0.00	0.00	0.00	0.20	3.6	* *
Bromus japonicus	0.00	0.00	0.00	0.10	1.25	0.30	4.9	3.0
Bromus squarrosus	0.00	0.00	0.00	0.00	1.80	0.40	5.0	* *
Bromus tectorum	0.00	0.00	0.00	0.00	0.00	0.20	5.0	* *
Calamagrostis canadensis	1.40	0.00	0.00	0.00	0.00	0.10	1.0	1.0
Carex brevior	0.00	0.90	0.20	0.10	0.10	0.30	2.6	3.0
Carex eleocharis	0.90	0.00	0.00	0.10	0.00	0.10	1.1	* *
Carex emoryi	12.30	6.10	4.50	2.10	1.50	4.60	2.0	1.0
Carex interior	0.50	0.00	0.60	0.10	0.00	0.20	1.7	1.0
Carex pellita	1.10	0.52	4.01	0.72	0.00	1.58	1.7	1.0
Carex praegracilis	0.00	0.00	1.10	0.10	0.10	3.30	1.6	2.0
Carex scoparia	1.40	0.00	0.50	0.00	0.00	0.20	1.4	1.0
Carex spp.	8.40	2.20	7.00	1.40	0.00	3.50	2.0	1.4
Carex tetanica	0.20	0.20	0.10	0.00	0.00	0.10	1.5	1.5
Carex vulpinoidea	0.60	0.00	0.00	0.00	0.00	0.10	1.0	1.0
Cyperus lupulinus	0.00	0.00	0.00	0.00	0.60	0.20	5.0	3.0
Cyperus spp.	0.00	2.50	0.00	0.00	0.00	0.50	2.0	* *
Dalea candida	0.00	0.00	0.00	0.10	0.20	0.10	4.8	* *

Table 1. (Continued)

	Percentage species composition when water table was:					Wetland classification		
Species	0-10	11-30	31-60	61-100	101+	Overall	Calculated	Table (Reed)
Dactylis glomerata	0.00	0.00	0.00	0.30	0.10	0.10	4.10	3.0
Desmanthus illinoensis	0.00	0.00	0.10	0.00	0.50	0.20	4.70	3.0
Dichanthelium acuminatum	0.40	3.80	1.50	1.00	0.20	0.70	2.60	3.0
Dichanthelium oligosanthes	0.00	0.00	0.10	0.00	0.50	0.10	4.70	4.0
Dichanthelium villosissimum	0.30	0.00	0.40	0.00	0.70	0.24	3.60	* *
Eleocharis elliptica	0.70	0.60	1.00	0.00	0.30	0.50	2.40	1.0
Eleocharis palustrus	0.90	1.00	0.00	0.00	0.00	0.20	1.50	* *
Eleocharis spp.	12.30	6.80	7.70	1.20	1.00	4.50	2.10	* *
Equisetum hyemale	0.00	0.00	0.60	0.10	0.10	0.20	3.30	2.0
Equisetum spp.	0.10	1.10	1.00	0.30	0.40	0.70	3.00	* *
Erigeron philadelphicus	0.00	0.00	0.00	0.00	1.60	0.40	5.00	* *
Erigeron strigosus	0.20	0.00	0.00	0.10	0.30	0.10	3.50	3.0
Glycyrrhiza lepidota	0.20	0.00	0.30	0.10	0.00	0.10	2.50	3.0
Helianthus maximilianii	0.00	0.00	0.00	0.00	2.30	0.60	5.00	5.0
Hordeum jubatum	0.40	0.00	0.30	0.20	0.00	0.30	2.00	1.0
Juncus balticus	1.80	1.40	1.20	0.30	0.00	0.90	2.30	1.0
Juncus interior	0.60	0.00	0.80	0.10	0.00	0.40	3.24	3.0
Juncus spp.	0.00	0.00	1.20	0.30	0.00	0.60	3.50	* *
Koeleria macrantha	0.00	0.00	0.20	0.20	0.00	0.10	3.50	3.0
Lepidium densiflorum	0.00	0.00	0.00	0.00	0.80	0.20	5.00	3.0
Liatris lancifolia	0.00	0.20	0.00	0.10	0.00	0.10	2.60	2.0
Lotus corniculatus	0.50	0.00	1.60	0.50	0.00	0.80	2.80	4.0
Lysimachia ciliata	1.40	0.00	0.00	0.00	0.00	0.30	1.00	2.0
Lythrum salicaria	0.00	1.00	0.00	0.00	0.00	0.20	2.00	1.0
Medicago lupulina	0.00	0.00	2.00	0.40	1.50	1.00	3.90	3.0
Melilotus alba	0.00	0.00	0.10	0.10	0.10	0.10	4.10	4.0
Mentha spp.	0.90	0.30	0.10	0.00	0.00	0.20	1.40	1.0
Moss	4.40	0.90	1.00	0.00	0.00	0.70	1.50	* *
Osmunda spp.	0.00	0.00	2.30	0.00	0.20	0.40	3.10	1.0
Panicum virgatum	0.00	3.10	6.50	2.80	5.30	3.50	3.50	3.0
Phalaris arundinacea	0.00	0.00	0.40	0.50	0.00	0.20	3.50	1.5
Phleum pratense	3.40	0.20	0.30	1.20	0.50	1.40	2.10	4.0

Table 1. (Continued)

Species	Percentage species composition when water table was: 0-10	11-30	31-60	61-100	101+	Wetland classification: Overall	Calculated	Table (Reed)
Phyla lanceolata	0.50	1.30	0.20	0.10	0.00	0.30	2.0	1.0
Physalis virginiana	0.00	0.00	0.00	0.40	0.00	0.10	4.0	3.0
Plantago patagonica	0.20	0.00	0.00	0.00	0.60	0.20	4.1	4.0
Poa compressa	1.80	0.00	0.00	0.00	0.00	0.30	1.0	4.0
Poa pratensis	4.30	3.30	6.60	6.40	18.00	11.10	3.8	4.0
Polygonum spp.	0.00	2.40	0.10	0.00	0.00	0.40	2.1	3.0
Prunella vulgaris	1.20	0.00	0.90	0.00	0.00	0.30	1.9	3.0
Psoralea argophylla	0.00	0.00	0.00	0.50	0.10	0.62	4.2	4.0
Psoralea esculenta	0.00	0.00	0.00	0.10	0.90	0.10	4.2	* *
Psoralea tenuiflora	0.00	0.00	0.00	0.10	0.00	0.10	4.0	* *
Rosa arkansana	0.00	0.00	0.20	0.30	1.20	0.50	4.2	3.0
Rudbeckia hirta	0.50	1.50	0.90	0.10	0.20	0.60	2.4	4.0
Rumex spp.	0.00	0.10	0.60	0.00	0.00	0.10	2.8	* *
Scirpus pungens	2.70	1.90	3.20	0.30	0.00	1.20	2.1	* *
Senecio plattensis	0.00	0.00	0.00	0.00	0.20	0.10	5.0	4.0
Setaria glauca	0.00	0.00	0.00	0.10	0.10	0.10	4.5	3.5
Smilacina stellata	1.20	0.50	1.20	0.50	0.60	0.80	2.7	* *
Sorghastrum nutans	4.50	0.20	0.60	0.40	0.90	1.10	2.0	3.0
Sparganium eurycarpum	0.00	0.40	0.00	0.00	0.00	0.10	2.0	1.0
Spartina pectinata	7.70	20.10	9.10	4.00	3.80	9.20	2.5	2.0
Sphenopholis obtusata	0.90	0.60	0.50	0.30	0.30	0.60	2.4	2.0
Stipa comata	0.00	0.00	0.00	0.00	1.40	0.30	5.0	* *
Stipa spartea	0.00	0.00	0.00	0.00	1.10	0.20	5.0	* *
Taraxacum officinale	0.00	0.40	0.20	0.00	0.50	0.40	3.6	4.0
Thalictrum dasycarpum	0.00	0.00	0.00	0.10	0.10	0.10	4.5	2.0
Toxicodendron radicans	0.00	0.00	0.00	0.10	0.30	0.10	4.7	4.0
Tragopogon dubius	0.10	0.00	0.00	0.00	0.40	0.10	4.1	* *
Trifolium pratense	1.00	1.70	4.50	2.40	0.00	3.20	3.0	4.0
Trifolium repens	1.10	0.90	0.50	1.10	0.10	1.20	2.2	4.0
Vernonia fasciculata	0.00	1.00	0.20	0.00	0.00	0.30	2.1	3.0
Vicia americana	0.00	0.00	0.00	0.00	0.50	0.10	5.0	* *
Viola pratincola	0.50	0.30	0.50	0.10	0.40	0.50	2.7	3.5

**Not listed in Reed (1988).

Table 2. Correlation matrix showing relationships between physical/chemical and biological components of the wetland ecosystem. Number of observation = 145.

	WATTAB	WAT3	WAT6	PENE3	PENE6	PENE9	PENE12	PENE15	PENE18	PENE21	PENE24	ORGMAT	RANGSI	AGST	ANGE	BPIN	CAEM
WATTAB	1.00																
WAT3	-0.45	1.00															
WAT6	-0.39	0.94	1.00														
PENE3	0.32	-0.45	-0.42	1.00													
PENE6	0.21	-0.30	-0.30	0.71	1.00												
PENE9	0.10	-0.17	-0.19	0.45	0.63	1.00											
PENE12	0.02	0.04	0.03	0.18	0.34	0.72	1.00										
PENE15	-0.06	0.16	0.14	0.11	0.26	0.51	0.76	1.00									
PENE18	-0.05	0.19	0.16	0.11	0.23	0.48	0.63	0.84	1.00								
PENE21	-0.15	0.21	0.14	0.07	0.19	0.44	0.60	0.74	0.86	1.00							
PENE24	-0.09	0.23	0.18	0.00	0.14	0.38	0.55	0.70	0.82	0.88	1.00						
ORGMAT	-0.22	0.39	0.35	0.05	0.08	0.22	0.27	0.27	0.31	0.29	0.29	1.00					
RANGSIT	-0.20	0.13	0.13	-0.18	-0.14	-0.20	-0.10	-0.08	-0.08	0.00	-0.03	-0.21	1.00				
AGST	-0.06	0.07	0.06	-0.02	0.01	0.11	0.21	0.22	0.10	0.09	0.10	0.01	-0.14	1.00			
ANGE	0.05	-0.03	-0.03	-0.01	0.00	-0.05	-0.12	-0.04	-0.05	-0.13	-0.11	-0.06	0.23	0.02	1.00		
BRIN	-0.02	-0.06	-0.09	0.01	0.16	-0.04	-0.06	-0.02	0.04	0.05	0.03	0.01	0.02	-0.12	-0.05	1.00	
CAEM	0.04	-0.26	0.34	0.04	0.00	0.01	-0.05	-0.10	-0.10	0.01	-0.03	-0.08	-0.11	-0.11	0.01	-0.04	1.00
CAPE	-0.04	0.13	0.15	-0.06	-0.10	-0.11	0.06	0.04	0.07	0.07	0.10	-0.01	-0.05	0.07	-0.13	-0.08	-0.07
CARE	-0.06	0.09	0.10	-0.06	-0.10	-0.09	0.05	0.04	0.06	0.08	0.10	-0.04	-0.07	0.02	-0.09	-0.09	0.13
ELEO	0.19	-0.15	-0.15	0.37	0.36	0.28	0.23	0.23	0.20	0.15	0.13	0.21	-0.06	-0.13	-0.14	-0.05	-0.04
EQHY	-0.16	0.17	0.14	-0.06	-0.08	-0.04	0.01	0.01	0.05	0.07	0.05	0.03	0.14	0.15	-0.11	-0.06	-0.07
EQUI	-0.17	0.16	0.14	-0.07	-0.09	-0.06	-0.01	-0.01	0.04	0.06	0.04	0.02	0.15	-0.17	-0.11	-0.02	-0.07
JUNC	0.39	-0.09	-0.05	-0.03	-0.04	-0.03	0.08	0.09	0.10	0.04	0.12	-0.09	-0.10	0.15	0.03	-0.08	-0.08
PHAR	0.22	-0.14	-0.14	0.15	0.17	0.16	0.07	0.03	0.06	0.02	0.07	-0.10	0.07	-0.14	-0.11	0.06	-0.04
PHPR	0.17	0.00	-0.01	0.03	0.18	0.23	0.28	0.26	0.22	0.16	0.15	-0.07	0.01	-0.09	-0.09	-0.03	-0.03
POPR	0.06	-0.01	-0.01	-0.07	-0.02	-0.01	0.05	0.08	0.02	0.02	0.06	-0.02	-0.07	0.19	-0.04	-0.03	-0.02
SCIR	0.17	-0.13	-0.12	0.17	0.10	0.08	0.05	0.02	0.05	0.08	0.03	-0.07	0.08	-0.23	-0.15	0.15	0.04
SPPE	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

	CAPE	CARE	ELEO	EQHY	EQUI	JUNC	PHAR	PHPR	POPR	SCIR	SPPE
CAPE	1.00										
CARE	0.95	1.00									
ELEO	-0.02	-0.03	1.00								
EQHY	0.04	0.01	0.08	1.00							
EQUI	0.03	0.00	0.08	0.99	1.00						
JUNC	-0.06	-0.09	0.12	-0.08	-0.09	1.00					
PHAR	-0.09	-0.1	0.04	0.11	0.11	0.25	1.00				
PHPR	-0.05	-0.06	0.14	-0.07	-0.07	0.12	0.21	1.00			
POPR	0.01	-0.01	-0.05	-0.01	-0.07	-0.07	-0.05	-0.03	1.00		
SCIR	-0.18	-0.14	-0.09	-0.19	-0.19	-0.08	0.09	0.03	-0.07	1.00	
SPPE	*	*	*	*	*	*	*	*	*	*	*

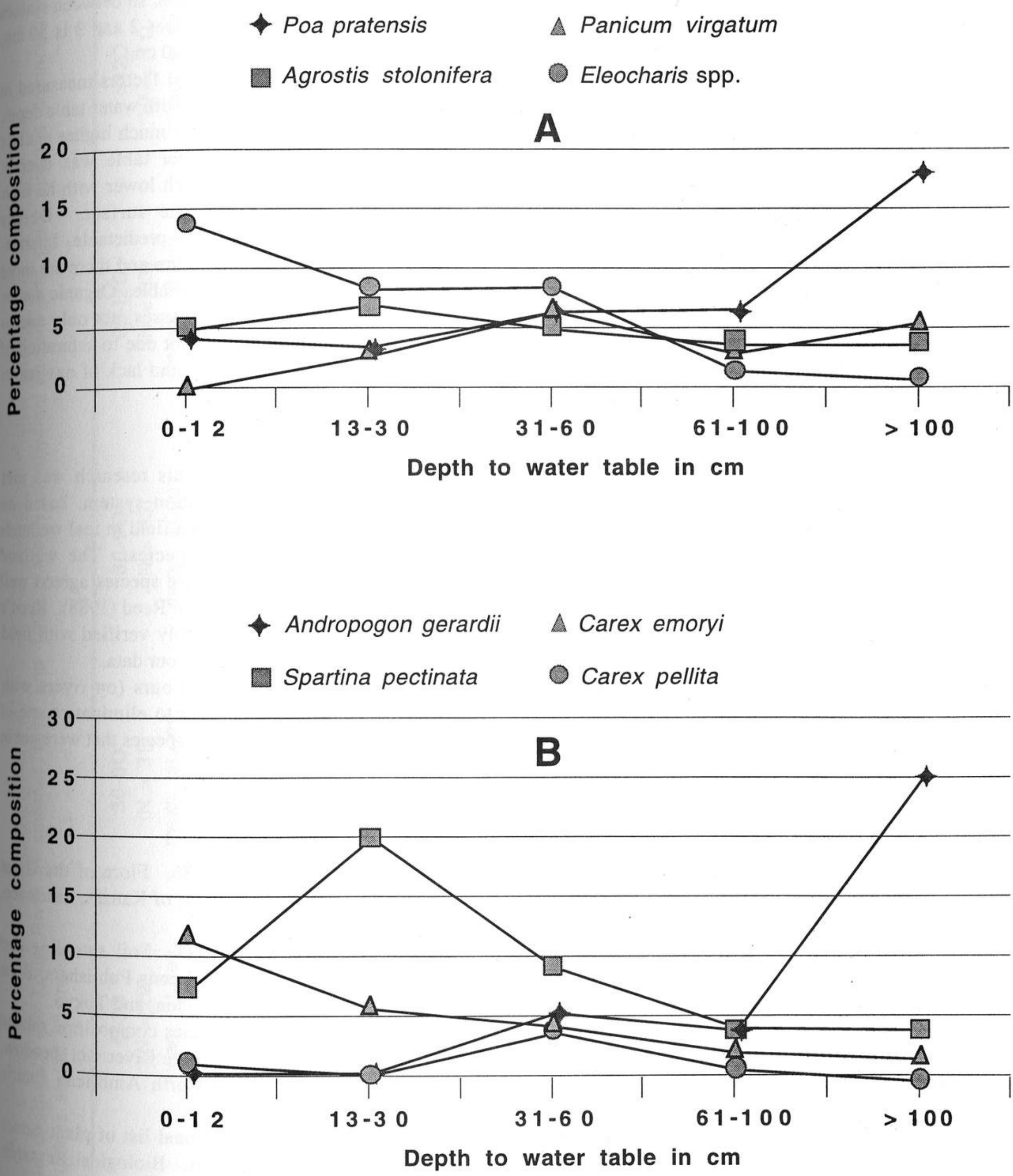

Fig. 2. Response of 8 of the most abundant plant species to water table depth along the Middle Loup River and Loup River in Nebraska, summers of 1996 and 1997. This shows how the dominant species divided up the water table aspect of the habitat among themselves.

POPR = *Poa pratensis* and PAVI = *Panicum virgatum*). In the real world, on the Loup River, not all species can have their optimum habitat all by themselves. Spikesedge and Emory's sedge are dominants at the wettest end, and big bluestem and Kentucky bluegrass dominate the drier end. Prairie cordgrass peaked at the second wettest ground water situation, but at water table depths 3 and 4, no dominant species existed.

Currier (1989) did similar research on the Platte River in Nebraska. His sampling was done over a 6-year period, which allowed him to track changes in species composition as ground water level changed. The Loup River water flows do not fluctuate much compared to the Platte. Although our readings of groundwater depth were done in June and July, they probably would not differ much over a multi-year period. Hydrographs during the period of sampling were uniform, except for a 3-day spike in June. We eliminated the samples taken during this 3-day period, but the results were not different from the analysis including all samples. Consequently, we left all samples in the analysis for this paper.

When Currier (1989) plotted dominant species, he found what was expected: a species being dominant at almost any water table depth. His dominant species differed somewhat from ours, which may explain the differences.

Several discrepancies exist between the calculated water table depth preference and the theoretical rating (Table 1). Reed canarygrass (*Phalaris arundinacea*) rated a 3.55 in fields along the Loup, while theoretically it preferred a 1.5. Several species of sedge, spikesedge, and rush (*Juncus* spp.) displayed the ability to live on drier sites than their preferred site would indicate. On the other hand, Indian grass (*Sorghastrum nutans*) lived on wetter sites than predicted by Reed (1988). (It lived on areas averaging 1.96, whereas preferred habitat was 3.0.) Purple meadowrue (*Thalictrum dasycarpum*) deviated more than any other species. It lived on areas scoring 4.5 while preferring sites rated 2.0.

Table 1 utilizes different sizes of range within each class. We assumed that obligate wetland plants would probably live inundated or at least with a saturated soil for the entire year. Since much of the soil on the Loup is quite sandy textured and has low organic content, that capillarity would not move the water upward more than 10 cm. Therefore, we used 10 cm deep as the maximum for Class 1, which we equated with obligate wetland species. This seemed to correlate fairly well with Reed's (1988) classification. Depth to groundwater then increased by the interval +10 cm each class, so between classes 1 and 2 is 20 cm, between classes 2 and 3 is 30 cm, and between classes 3 and 4 is 40 cm.

Table 3 shows the physical factors measured in the soil and how they changed with water table depth. Water content, as expected was much higher in class 1 and 2 than where the water table was deeper. Penetrometer readings are much lower with he high water table, at least near the surface. Deeper penetrometer readings are not as predictable. Interacting with the water table is texture and there are more sandy sites with a deeper water table. Organic matter was highest in the 3 wettest classes, not only due to higher primary productivity, but due to saturation of the soil with high water table and lack of oxygen to decompose organic mater.

CONCLUSIONS

The main objective of this research was met fairly well. Our classification system, based on empirical data collection in the field in real wetlands was applied to 102 plant species. The wetland coefficients we found for these species agreed well with the classification system of Reed (1988). Reed's system, although not thoroughly verified with field data, was petty well verified by our data.

Future studies similar to ours (on rivers with stable water tables) may help to eliminate some of the differences among the few species that were not in agreement.

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Table 3. Water table depths of the Loup River in summer 1996 and 1997. Mean of physical factors and plant species composition. Measurements in cm unless stated otherwise.

ITEM	0-30 (N = 29) mean	st.dev	30-60 (N = 31) mean	st.dev.	60-90 (N = 43) mean	st.dev.	90-120 (N = 33) mean	st.dev.	>120 (N = 11) mean	st.dev.
watertable depth	16.0	7.3	47.3	8.3	73.7	9.3	103	17.9	204	124
water content 3"	8.4	2.1	8.3	2.0	7.7	3.0	8.7	4.4	4.1	2.4
water content 6"	7.7	2.1	8.3	2.1	7.7	3.1	6.5	3.5	4.0	2.5
penetrometer 3"	109	81	115	66	179	136	179	86	270	96.0
penetrometer 6"	159	82	204	154	224	133	216	59	279	98.0
penetrometer 9"	199	71	264	134	293	179	260	88	267	59.0
penetrometer 12"	247	107	309	138	399	179	338	166	283	57.0
penetrometer 15"	325	158	360	154	587	1163	345	195	307	89.0
penetrometer 18"	380	161	365	151	630	1233	362	235	254	89.0
penetrometer 21"	360	188	377	178	495	238	383	195	300	146
penetrometer 24"	333	217	437	202	508	245	397	227	312	189
organicmatter	2.7	1.0	2.9	1.2	2.8	1.4	2.4	0.9	1.4	0.6
range site*	5.7	1.0	5.6	1.8	5.7	1.3	5.2	2.5	5.1	1.5
redtop	6.8	12.8	2.4	4.5	9.3	11.6	5.8	9.5	4.8	7.2
big bluestem	4.1	10.4	13	16.3	8.3	13.2	10.7	15.2	20.2	27.7
smooth brome	0.0	0.0	2.2	5.7	0.6	3.1	0.1	0.5	1.8	5.7
Japanese brome	0.0	0.0	0.3	1.8	13.0	11.0	0.8	3.0	0.0	0.0
Emory's sedge	4.0	11.7	5.2	12.2	5.4	12.0	4.2	9.9	3.6	11.6
other sedges	3.6	10.7	0.7	2.5	2.2	9.5	0.0	0.0	0.4	1.4
spikesedge	7.5	15.5	7.1	13.7	3.1	6.5	0.3	1.6	5.9	14.7
scouring rush	0.9	1.8	1.1	1.8	0.3	0.8	2.6	5.3	1.0	2.9
rushes	0.7	2.2	1.0	3.2	0.6	1.3	0.1	0.2	0.0	0.0
reed canarygrass	0.0	0.0	0.5	2.6	0.1	0.3	0.6	1.8	1.7	3.0
reedgrass	0.4	1.4	0.4	1.6	0.9	4.7	0.6	3.4	1.2	3.8
Kentucky bluegrass	7.5	11.2	5.6	7.4	11.7	18.8	14.7	22.7	23.6	26.0
bulrush	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	2.9
prairie cordgrass	12.6	18.0	9.7	17.4	8.0	13.2	9.0	14.9	4.8	8.7

MULTISPECTRAL VIDEOGRAPHY FOR DISTINGUISHING COASTAL PRAIRIE MARSHES IN TEXAS

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Abstract: Multispectral videography was used to compare species composition and pattern of occurrence among a brackish marsh , a salt marsh, and 3 small freshwater marshes in the semiarid coastal zone of southern Texas. The line intercept method of vegetation analysis was used to provide ground truth and to quantify the distribution and abundance of species. The vegetation of the brackish marsh and salt marsh was arranged into 3 zones along an elevation gradient. The vegetation of the freshwater marshes was not zoned. Maritime saltwort (*Batis maritima*) is the dominant species at the lowest elevations in the brackish marsh and the salt marsh. Intermediate elevations in the brackish marsh are dominated by shoregrass (*Monanthochloe littoralis*), and coastal sacahuista (*Spartina spartinae*) is the the dominant at higher elevations. In the salt marsh, the positions of the shoregrass zone and the coastal sacahuista zone are reversed. Ephemeral freshwater marshes are dominated by an array of grasses and sedges. None of the species present in the freshwater marshes occurred in the brackish marsh or salt marsh. Zonation of the dominant species in the brackish marsh and salt marsh is clearly distinguished by a distinctive signature in multispectral videography. However, the technology is less useful for discriminating species composition and pattern in small-area ephemeral freshwater marshes on South Padre Island.

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Key words: brackish marshes, coastal sacahuista, freshwater marshes, maritime saltwort, *Monanthochloe littoralis*, *Batis maritima*, remote sensing, salt marshes, shoregrass, southern Texas, *Spartina spartinae*.

The southernmost extension of prairie in the United States is located in the Gulf Prairies and Marshes vegetational area of Texas. The Gulf Marshes, including approximately 202,000 ha (500,000 acres), occur on the barrier islands in the Gulf of Mexico and on the adjacent narrow belt of lowlands on the Texas mainland from Louisiana to Mexico. The much larger (3,640,000 ha) (9 million acres) Gulf Prairies extend 48 to 128 km (30 to 80 miles) inland from the Gulf Marshes (Schuster and Hatch 1990).

The southernmost tip of Texas is characterized by barrier islands (Boca Chica, Brazos, and South Padre Island), an enclosed lagoon (Laguna Madre), and the delta of the Rio Grande on the Texas mainland. The climate of the area is semiarid and subtropical (Lonard et al. 1991). Average annual precipitation is about 68 cm (26.8 in.) and freezing temperatures occur for a few hours in 1 out of 6 years.

Marsh systems along the semiarid south Texas coast are limited in areal distribution, variety, and stability when they are compared with marshes present in the higher rainfall belts in the central and northern portion of the Texas coastal zone (Brown et al. 1980). It is difficult to distinguish between salt marshes and brackish marshes, brackish marshes and freshwater marshes, and brackish marshes and the drier vegetated saline flats in this semiarid region (White et al. 1986). Major reasons for these difficulties are the flat terrain with an average slope of 0.29 m/km to 0.38 m/km (1.5 ft/mi to 2.5 ft/mi) (Brown et al. 1980), a climate where evaporation exceeds rainfall (Thornthwaite 1948), the proximity to the Laguna Madre, prevailing southeasterly winds that carry salt spray, and high tides during tropical storms that drive salt water inland along drainage courses (Judd et al. 1997a).

There have been no studies presenting quantified data on the marsh communities of the Rio Grande Delta except those of Judd et al. (1997a, 1997b). Johnston (1955, 1963) referred to the poorly-drained flats at elevations from 0 to 3 m (0 to 10 ft) above sea level as a "*Borrichia* flat." He reported on the distribution pattern of marsh communities along an elevation gradient, but he did not provide data quantifying dominance. He noted that at low elevations a community of maritime saltwort (*Batis maritima*), dwarf saltwort (*Salicornia virginica*), and seepweed (*Suaeda* sp.) grades almost imperceptibly into slightly higher elevations characterized by sea-ox-eye daisy (*Borrichia frutescens*), maritime saltwort, and shoregrass (*Monanthochloe littoralis*), which in turn grades upward into a community of coastal sacahuista (*Spartina spartinae*).

White et al. (1986) used color-infrared photographs to identify and map wetlands in the Rio Grande delta. They recognized 7 major kinds of vegetated wetlands including salt marshes, brackish marshes, and freshwater marshes. They distinguished marshes on the basis of elevation, soil, surface moisture, and vegetation. Lists of species characteristic of each type of marsh were provided, but many of the species used to characterize the vegetation of a given type of marsh were listed as characteristic of 1 or both of the other types of marsh. There was no quantification of the abundance of species or communities, and no data were provided on the "signatures" (i.e. color, hue, and texture) of species or communities.

Recently, Judd et al. (1997a) reported that the vegetation of a typical brackish marsh is organized into 3 zones along an elevation gradient. At the lowest elevations, there is a distinct zone dominated by maritime saltwort. Where rainwater remains the longest at the lowest elevations, stands of California bulrush (*Scirpus californicus*) are present. An intermediate elevation zone supports shoregrass as the dominant species. The highest elevation zone is dominated by coastal sacahuista. The upper margin of this zone grades gradually into a shrub-grassland community that occurs on clay dunes (lomas) in the area. Each of these zones is distinguished by a distinctive signature in multispectral videography.

Judd et al. (1997b) indicated that a representative salt marsh is zoned and has the same dominant species (excepting California bulrush) as a brackish marsh, but the positions of the shoregrass and coastal sacahuista zones are reversed in the salt marsh. That is, coastal sacahuista occurs at intermediate elevations and shoregrass is present at higher elevations. They concluded that the positions of these 2 communities may be used in distinguishing between brackish marshes and salt marshes.

Mapping the extent of coastal wetlands and assessing long-term changes in vegetation is most efficiently achieved using remotely sensed data. Airborne systems such as digital photography and multispectral videography can acquire data relatively inexpensively, but these systems have not been adequately calibrated for quantitative characterization of marsh ecosystems. Herein we report the results of an investigation of the feasibility of using multispectral videography to compare the species composition and pattern of distribution among a salt marsh, a brackish marsh, and a freshwater marsh.

STUDY AREAS

The largest remaining tracts of relatively undisturbed marshes in southern Texas are found in the Laguna Atascosa National Wildlife Refuge (LANWR) of the Rio Grande delta and on South Padre Island (SPI). LANWR occupies 19,680 ha (48,629 acres) of the delta adjacent to the Laguna Madre on the coastal mainland. This southernmost waterfowl refuge in the Central flyway was established in 1946. It includes about 9,720 ha (24,018 acres) of wetlands (Jahrsdoerfer and Leslie 1988). Soils at LANWR belong to the Laredo-Lomalta association. This association, which is of Holocene-Modern geological origin, is characterized as having moderately permeable to very slowly permeable, saline, clayey or loamy soils (Williams et al. 1977).

South Padre Island, 55 km (34.2 miles) long with an area of 16,200 ha (40,030 acres), is separated from the coastal mainland by the shallow waters of the Laguna Madre. Deflation swales in the Secondary Dunes and Vegetated Flats topographic zone (Judd et al. 1977) on the island often support the development of localized freshwater marshes and brackish marshes. These wetland plant communities are dominated by a combination of grasses and sedges including American bulrush (*Scirpus pungens*), marshhay cordgrass (*Spartina patens*), fimbry (*Fimbristylis castanea*), Western umbrellagrass (*Fuirena simplex*), and starrush umbrellagrass (*Rhynchospora colorata*) (Judd et al. 1977). Soils on SPI are also of Holocene-Modern geological origin and are listed in the Mustang-Coastal dunes association. This association is characterized as having nearly level to steep, rapidly permeable to poorly drained fine sands and sand dunes (Williams et al. 1977).

MATERIALS AND METHODS

The line intercept technique was used to provide ground truth information and to quantify vegetation abundance and distribution at a brackish marsh (26°10'21"N, 97°19'53"W) and a salt marsh (26°13'01"N, 97°19'00"W at LANWR and at 3 small discontinuous freshwater marshes (26°12'42"N, 97°10'82"W; 26°12'35''N, 97°10' 83"W; 26°12'42"N, 97°10'87''W) on SPI (Canfield 1941, Judd et al. 1977). At each marsh at LANWR, 3 transects were established along an elevation gradient ranging from the low point of the marsh up the elevation gradient until an interval with shrubs and trees was encountered.

On SPI, transects were established along the length of 3 narrow, linear-configured freshwater marshes. Transects extended from the low point in the shallow depressions to a slight elevational rise dominated by seacoast bluestem (*Andropogon* [*Schizachyrium*] *scoparius* [*scoparium*] var. *littorale*) Each transect was divided into 10-m (33-ft) intervals and data were recorded along the total length of each interval. Each species intercepted by the line was rated individually and scored with separation into strata. We recorded foliage cover and calculated relative cover from these data. Frequency of occurrence was used to determine species distribution along the transect and to assess contiguity between species.

At the brackish marsh, Transect 1 was completed on 31 May 1996 and Transects 2 and 3 were completed 16 November. At the salt marsh, Transect 1 was completed on 9 August 1996 and Transects 2 and 3 were completed on 12 October. At the freshwater marsh, vegetation sampling was conducted 6 June 1998 on SPI.

Imagery of the study sites was obtained with a 3-camera multispectral digital video imaging system (Everitt et al. 1995) on 6 June 1996 for the brackish marsh and the salt marsh at LANWR and on 14 May 1997 for the freshwater marshes on SPI using a fixed-wing Aerocommander[1] aircraft. Imagery was taken between 1100 and 1400 hours under sunny conditions. The system is comprised of 3 charge-coupled device video cameras and a computer equipped with an image digitizing board. The cameras are visible/near-infrared (NIR) (400 to 1100 nm) light sensitive. One camera had a NIR (845 to 857 nm) filter, 1 had a red (R) (625 to 635 nm) filter, and the other camera a yellow-green (YG) (555 to 565 nm) filter. The computer was a 486-DX50 system that had an RGB grabbing board (640 x 480 pixel resolution). The NIR, R, and YG image signals from the cameras were subjected to RGB inputs of the computer digitizing board, thus giving a color-infrared (CIR) composite digital image similar in color rendition to that of CIR film. The hard disk could store 1,000 CIR composite images. Video imagery of the 2 study sites at LANWR was obtained at 460 m (1,500 ft) above ground level and provided a horizontal ground pixel size of 0.5 m (1.6 ft). Video imagery of the freshwater marsh study site on SPI was obtained at an altitude of 200 m (660 ft) above ground level and provided a horizontal ground pixel size of 0.22 m (0.72 ft).

[1] Trade names are included for the benefit of the reader and do not imply an endorsement of or a preference for the product listed by the U.S. Department of Agriculture.

RESULTS AND DISCUSSION

Brackish Marsh

Judd et al. (1997a) reported data for a brackish marsh at LANWR. Table 1 shows the distribution of dominant species, their cover, the total number of species per interval, and the number of layers of vegetation in each interval of the 3 transects. Table 1 shows that the dominant species are zoned in 3 belts. Transects 2 and 3 were sampled in mid-November when there was water at the lowest elevations in the marsh. California bulrush was the dominant species on both transects where water was 0.5 m (1.6 ft) deep. A succulent halophyte, maritime saltwort, was the dominant species in the first belt at low elevations on all 3 transects. Sea-ox-eye daisy was a dominant in interval 3 of Transect 2 of this belt. Seashore dropseed (*Sporobolus virginicus*) and Carolina wolfberry (*Lycium carolinianum*) were species of minor importance (< 2.5% cover).

Shoregrass, which forms dense mats 10 to 15 cm (4 to 6 in) high, was the dominant species in all 3 transects at intermediate elevations in the brackish marsh. This belt was about 40 m (130 ft) wide in all transects. Shoregrass accounted for more than 50% of the relative cover in all but 1 interval. Sea-ox-eye daisy, maritime saltwort, seashore dropseed, and creeping mesquite (*Prosopis reptans*) extended into this zone.

At higher elevations in the brackish marsh where marsh vegetation graded into shrub-grassland on a loma, coastal sacahuista was the dominant species. Species richness was greatest in this higher elevation zone in all transects. Several shrubs including tenaza (*Pithecellobium pallens*), cenizo (*Leucophyllum frutescens*), and narrowleaf forestiera (*Forestiera angustifolium*) and the arborescent, Trecul yucca (*Yucca treculeana*), added to the higher species richness of this zone. Species richness was usually greatest at the highest elevations and was least at the lower elevations.

Fig. 1A shows that the brackish marsh vegetation is clearly zoned. The area was in a protracted drought at the time the imagery was

Table 1. Comparison of dominant species among intervals and transects of a brackish water marsh at Laguna Atascosa National Wildlife Refuge. 1 m=3.2 ft.

Interval (m)	Dominant Species	% Cover Rel.	Cover	# Species	# Layers
Transect 1					
0-10	maritime saltwort	71.3	81.6	3	2
10-20	maritime saltwort	67.5	64.6	5	2
20-30	maritime saltwort	70.3	78.9	4	2
30-40	maritime saltwort	59.9	69.3	3	1
40-50	shoregrass	57.7	54.8	4	2
50-60	shoregrass	97.5	74.8	4	2
60-70	shoregrass	85.6	85.8	5	2
70-80	shoregrass	97.5	78.2	5	2
80-90	coastal sacahuista	77.0	89.3	4	2
90-100	coastal sacahuista	44.3	45.1	6	2
100-110	coastal sacahuista	27.3	38.8	9	2
110-120	coastal sacahuista	52.5	46.3	8	3
120-130	coastal sacahuista	49.0	47.1	7	3
Transect 2					
0-10	California bulrush	7.1	52.6	3	2
10-20	maritime saltwort	8.8	74.5	3	2
20-30	sea-ox-eye daisy	13.7	48.1	4	1
30-40	shoregrass	56.5	63.8	6	2
40-50	shoregrass	86.5	71.8	5	2
50-60	shoregrass	89.1	69.9	5	2
60-70	shoregrass	19.8	22.4	10	3
70-80	coastal sacahuista	45.8	41.5	12	4
Transect 3					
0-10	California bulrush	14.7	73.5	2	2
10-20	maritime saltwort	19.9	87.3	2	1
20-30	maritime saltwort	12.8	50.6	3	1
30-40	shoregrass	56.0	63.1	6	1
40-50	shoregrass	100.0	65.8	4	2
50-60	shoregrass	92.6	64.0	6	2
60-70	shoregrass	53.8	57.2	9	2
70-80	coastal sacahuista	77.0	57.2	6	3

obtained, and the marsh was nearly dry. The maritime saltwort community (at the lowest elevation zone) has a bright pink to red image response. The shoregrass community (comprising the intermediate elevation zone) has a dark brown tonal response. The coastal sacahuista community (in the higher elevation zone) has a light gray to pinkish-tan hue. Bright red signatures to the left and above the coastal sacahuista zone are the canopies of trees and shrubs. Bare soil is white, and the bright blue response in the upper middle of the image is water.

Salt Marsh

Judd et al. (1997b) reported data for a salt marsh at LANWR. Table 2 shows the distribution of dominant species, their cover, the total number of species per interval, and the number of layers of vegetation in each interval of the 3 transects. In the predominantly barren lower elevations, maritime saltwort, is the dominant species. Dwarf saltwort also is present in this zone, but it contributes less than 6% of the relative cover in 1 interval in Transect 2. An abrupt vertical rise about 0.5 m

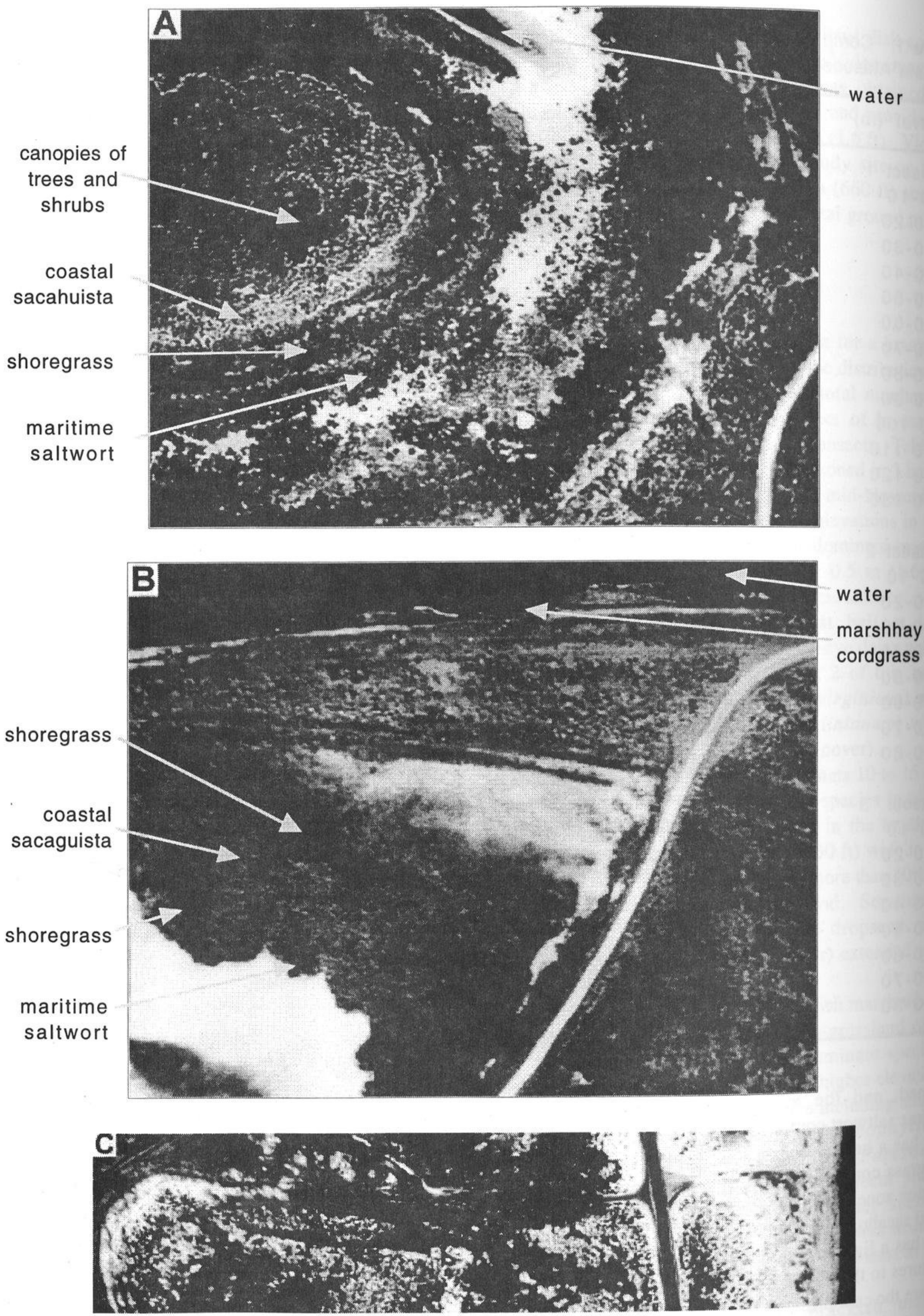

Fig. 1. Vegetation zones in a brackish marsh (A), a salt marsh at Laguna Atascosa National Wildlife Refuge (B), and unzoned freshwater marshes on South Padre Island (C).

Table 2. Comparison of dominant species among intervals and transects of a salt water marsh at Laguna Atascosa National Wildlife Refuge. 1 m = 3.2 ft.

Interval (m)	Dominant Species	% Cover	Rel. Cover	# Species	# Layers
Transect 1					
0-10	maritime saltwort	3.1	100.0	1	1
10-20	bare	0.0	0.0	0	0
20-30	bare	0.0	0.0	0	0
30-40	bare	0.0	0.0	0	0
40-50	maritime saltwort	25.6	100.0	1	1
50-60	coastal sacahuista	80.3	89.0	3	1
60-70	coastal sacahuista	100.0	94.2	3	1
70-80	coastal sacahuista	100.0	96.8	2	1
80-90	coastal sacahuista	100.0	95.0	3	1
90-100	coastal sacahuista	88.2	72.9	6	3
100-110	shoregrass	48.2	44.6	7	2
110-120	shoregrass	87.4	91.5	5	2
120-130	shoregrass	95.4	90.4	4	2
130-140	shoregrass	91.4	92.4	3	2
140-150	shoregrass	51.6	82.8	4	2
150-160	shoregrass	26.6	52.6	9	2
160-170	seashore dropseed	47.6	48.2	7	2
170-180	coastal sacahuista	37.3	48.3	9	2
180-190	big sacaton	29.1	35.7	8	3
Transect 2					
0-10	maritime saltwort	8.3	94.3	2	1
10-20	maritime saltwort	4.5	100.0	1	1
20-30	bare	0.0	0.0	0	0
30-40	bare	0.0	0.0	0	0
40-50	bare	0.0	0.0	0	0
50-60	coastal sacahuista	64.8	57.5	6	2
60-70	coastal sacahuista	100.0	95.1	2	1
70-80	coastal sacahuista	100.0	92.0	2	1
80-90	coastal sacahuista	100.0	96.1	3	1
90-100	coastal sacahuista	100.0	95.7	2	1
100-110	coastal sacahuista	75.0	79.8	10	2
110-120	sea-ox-eye-daisy	28.9	42.6	8	2
120-130	shoregrass	60.5	86.1	7	2
130-140	shoregrass	86.9	79.7	5	2
140-150	shoregrass	69.9	85.7	4	1
150-160	shoregrass	38.9	59.3	4	1
160-170	shoregrass	13.2	34.8	5	1
170-180	dwarf saltwort	18.0	34.7	7	1
180-190	seashore dropseed	25.4	41.6	10	2

Table 2. Continued

Interval (m)	Dominant Species	% Cover	Rel. Cover	# Species	# Layers
Transect 3					
0-10	maritime saltwort	15.5	100.0	1	1
10-20	bare	0.0	0.0	0	0
20-30	bare	0.0	0.0	0	0
30-40	bare	0.0	0.0	0	0
40-50	bare	0.0	0.0	0	0
50-60	coastal sacahuista	49.4	71.3	4	2
60-70	coastal sacahuista	100.0	83.2	2	1
70-80	coastal sacahuista	100.0	85.0	2	1
80-90	coastal sacahuista	92.8	93.8	4	2
90-100	coastal sacahuista	100.0	98.8	2	1
100-110	coastal sacahuista	100.0	67.1	6	3
110-120	shoregrass	36.9	42.4	9	2
120-130	shoregrass	67.9	66.3	9	2
130-140	shoregrass	63.1	63.3	9	2
140-150	shoregrass	32.4	40.6	7	2
150-160	shoregrass	32.4	43.7	11	2
160-170	seashore dropseed	23.9	30.1	12	2

(1.6 ft) in height distinguishes the change from the lowest elevation to intermediate elevations. The vegetation also shows an abrupt change to a zone dominated by coastal sacahuista. Sea-ox-eye daisy is common in this zone, but it does not exceed 29% cover in 1 interval in Transect 2. At slightly higher elevations, above the coastal sacahuista zone, shoregrass is the dominant comprising 45% to 92% of the relative cover. A community dominated by seashore dropseed, big sacaton (*Sporobolus wrightii*), or coastal sacahuista occurs above the shoregrass zone. This community inclines gradually into a shrub-grassland community typical of the lomas in the area.

All transects in the salt marsh show similar patterns characterized by a maritime saltwort community at the lowest elevations, a coastal sacahuista community at intermediate elevations, and a shoregrass community at higher elevations. Species richness increases with increasing elevation. However, species richness is relatively high in the transition from the coastal sacahuista to a shoregrass community.

Only 1 layer of vegetation is present in the maritime saltwort community. The coastal sacahuista community had 1 to 3 layers of vegetation. Sea-ox-eye daisy comprised the lowest layer, coastal sacahuista the intermediate layer, and yucca and other shrubs the tallest layer.

Figure 1B shows that the salt marsh is clearly zoned. At the lowest elevations, the maritime saltwort community has a bright pink to red tonal response, but most of the area is bare. The coastal sacahuista community at intermediate elevations appears light gray to pinkish tan. Discrete, circular clumps of coastal sacahuista are noted in this belt. The shore grass community at higher elevations has a dark brown to tan signature. The narrow, reddish brown tonal response adjacent to both margins of the abandoned road is the community dominated by either seashore dropseed, big sacaton, or coastal sacahuista. Pink and red clusters at the highest elevations on the loma represent Trecul yucca, mesquite (*Prosopis glandulosa*), huisache (*Acacia smallii*) and other shrubs. The narrow, dark red band on the margin of the dark blue water of the Laguna Madre is marshhay cordgrass (*Spartina patens*).

Freshwater Marshes

Table 3 shows the distribution of dominant species, their absolute and relative cover, the number of species per interval, and the number of layers of vegetation in each interval of the 3 transects in the freshwater marshes on SPI. None of the species present in the salt marsh or brackish marsh occurred in the freshwater marshes. Vegetation is 1- or 2-layered. Species in the freshwater deflation depressions on the barrier island are not zoned into distinct

Table 3. Comparison of dominant species among transects in 3 small, discontinuous freshwater marshes on South Padre Island. 1 m = 3.2 ft.

Interval (m)	Dominant Species	% Cover	Rel. Cover	# Species	# Layers
Transect 1					
0-10	starrush umbrellagrass	19.1	45.4	11	1
10-20	seacoast bluestem	8.1	22.3	11	2
20-30	gulf-dune paspalum	9.0	32.3	8	1
Transect 2					
0-10	coastal water hyssop	33.5	40.9	10	2
10-20	coastal water hyssop	59.4	59.8	7	2
20-30	American bulrush	23.8	40.9	9	2
Transect 3					
0-10	Western umbrellagrass	21.0	42.5	13	1
10-20	Western umbrellagrass	25.6	43.1	8	1
20-30	bushy bluestem	13.9	22.3	13	2

belts. Grasses and sedges, including starrush umbrellagrass, seacoast bluestem, and gulf-dune pasplalum, were the leading dominants in Transect 1. Indeed, grasses and sedges accounted for 91.5%, 91.1%, and 67.8% of the relative cover in the 3 intervals of Transect 1. The only forb that contributed more than 6% absolute cover was narrowleaf marshelder (*Iva augustifolia*). American bulrush was conspicuous in each interval, but it did not account for more than 4% absolute cover in any interval.

The stoloniferous, mat-forming coastal water hyssop (*Bacopa monnieri*) was the dominant species in 2 intervals of Transect 2, and American bulrush was the dominant in the third interval. The vegetation was distinctly 2-layered with either Western umbrellagrass or American bulrush comprising the upper layer and coastal water hyssop dominating the lower layer. In contract to Transect 1, grasses and sedges accounted for only 54.7%, 39.3%, and 62% of the relative cover in the 3 intervals.

Western umbrellagrass was the dominant species in 2 intervals of Transect 3, and bushy bluestem (*Andropogon glomeratus*) was the dominant at the lowest elevation in the depression. The grass and sedge aspect of the ephemeral freshwater marsh was noted by relative cover values of 63.8%, 92.2%, and 69.8%, respectively, for the 3 intervals in the transect. The only conspicuous forbs in the transect were narrowleaf marshelder and seaside goldenrod (*Solidago sempervirens*), but they contributed only 12.6% and 8.2% of the absolute cover in intervals 1 and 3, respectively.

Fig. 1C depicts a trans-island video image of South Padre Island obtained at an altitude of about 200 m (656 ft) above ground level. Ephemeral freshwater marshes that held standing water or had saturated soil when the imagery was obtained appear black in the scene. Multispectral videography is useful in delimiting topographic features that include small freshwater marshes on SPI. However, the technology is less useful in species identification due to the dominance of grasses and sedges in the swales. Grasses and sedges have reduced leaf surface areas and erectophile leaf orientations which are not easily detected in the imagery.

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PROPAGATION OF MEAD'S MILKWEED

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Abstract: Mead's milkweed, *Asclepias meadii* Torr. *ex* Gray, is federally listed as a threatened species by the US Department of Interior, Fish & Wildlife Service (USFWS). The species is found primarily on protected remnant prairies of eastern Kansas and west central Missouri. There is interest in developing a plan to reestablish the species to additional locations in Kansas. Extremely limited information is available on the species. Published information on the germination requirements, propagation techniques, or establishment of Mead's milkweed is not known to exist. This phase of the study focused on seed germination parameters following periods of cold-moist stratification. It was conducted in cooperation with the Kansas Biological Survey and the USFWS. Seeds were collected from 4 separate patches on the University of Kansas Ecological Reserves near Lawrence, Kansas. The seeds were cold-moist stratified for a minimum of 6 weeks. Seeds were then tested under 3 alternating (8/16 h) temperature regimes, 20/24°C, 10/30°C, and 20/30°C, at 2-week intervals. The germination rate following incubation at 20/24°C ranged from 90-100%, while the rate for the 10/30°C temperature regime ranged from 0-80%. Non-germinating seeds from the 10/30°C temperature regime were returned to cold-moist stratification. After 4 weeks additional stratification the remaining seeds germinated when incubated at 20/24°C to attain 100% germination. The seedlings were successfully transferred to 10.2 cm^3 "cone-tainers."

PROCEEDINGS OF THE NORTH AMERICAN PRAIRIE CONFERENCE 16:235-242

Key words: *Asclepias meadii*, cone-tainers, Kansas Biological Survey, Kansas Ecological Reserve, seed germination, floral transplants.

Mead's milkweed (*Asclepias meadii* Torr.) is a rare perennial herb found on calcareous soils of prairies (Fig. 1). The species is known to occur from southern Wisconsin and western Illinois west to the eastern edge of the Great Plains in Missouri, eastern Kansas, and southern Iowa (Barkley 1986).

Most site records are from protected remnant prairies of extreme eastern Kansas and west central Missouri, according to Barkley (1977). This species is federally listed as a threatened species by the US Department of Interior-Fish & Wildlife Service (USFWS). Interest in reestablishing the species in Kansas has prompted a need for technical information on propagation and establishment procedures. This study is a cooperative effort between the USDA-Natural Resources Conservation Service, Plant Materials Center, Man-hattan, Kansas, Kansas Biological Survey, and the USFWS. The study is being conducted under a permit authorized by the USFWS. A plan was developed in 1996 to address needs identified by the Kansas Biological Survey.

MATERIALS AND METHODS

Four Mead's milkweed seed pods were collected in 1996 on the Kansas Ecological Reserve near Lawrence, Kansas. Each pod was labeled with a patch number in the field. The seeds were processed at the Plant Materials Center. Shriveled seed units were discarded and the coma was removed from the remaining seed units. (See Table 1 for seed pod yield data.)

Seeds from each patch (here after referred to as seed lots) were surface sterilized using a 10:1 dH_20 (distilled water):sodium hypochlorite (5.25% A.I.) solution for 20 min with agitation. The seeds were triple rinsed in dH_20 for 2 min each rinse.

Initially three temperature regimes were selected for study, 22°C, and alternating temperatures of

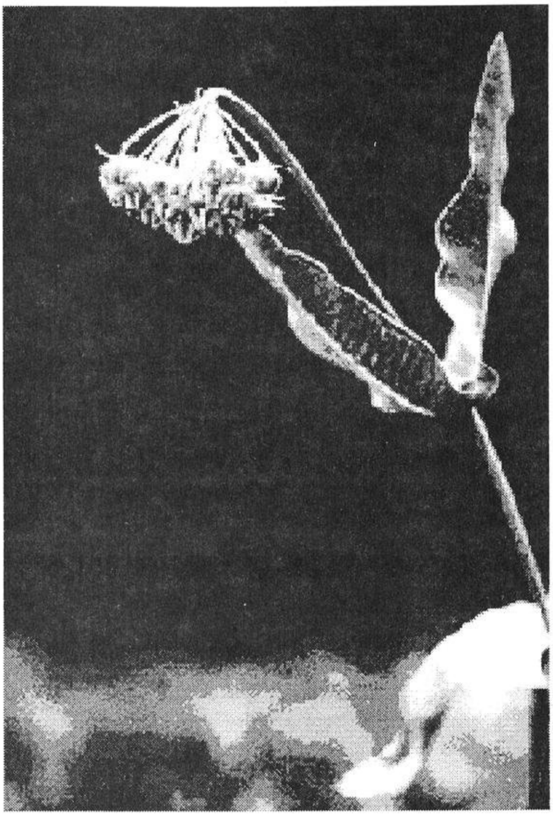

Fig. 1. Mead's milkweed, *Aesclepias meadii*, inflorescence. (USFWS file photo by John Schwegman).

10/30°C ± 2°C, and 20/30°C ±2°C (16 h/8 h). Eight hours of light and 16 hours darkness were common to all three temperature regimes. The constant 22°C temperature was not achieved. However an alternating temperature of 20/24°C was realized and maintained throughout the study.

A time zero planting was made from the 3 largest seed lots. Ten seeds from each lot were placed in petri dishes on two layers of Whatman filter paper soaked with dH_20 and placed in a diurnal growth chamber (hereafter referred as a germinator) at 20/24°C. The remainder of the seed units were placed in plastic boxes between moist blotters and refrigerated at 3-4°C for various periods to provide cold-moist stratification. Seeds were periodically taken from refrigeration and placed on top of blotters in 4x4 plastic boxes (Fig. 2).

Transplanting

Seedlings were transplanted from germination boxes to 10.2 cm^3 "cone-tainers" containing PRO-MIX BX soilless mix. The cones were then placed on the bottom shelf in the respective germinator. The cool white fluorescent tubes (F15T12/CW 15 W) above the transplants were later replaced with grow lights (F15T12/AGRO 15 W). The seedlings were transferred to the greenhouse after several weeks in the germinators before being transferred to the lath house. Other transplants were transferred directly from the germinator to the lath house.

Eventually the transplants were repotted to 25.4 cm^3 "cone-tainers" and maintained in the lath house for the growing season.

Field Establishment

Seven plants from the miscellaneous seed lot were transplanted from 10.2 cm^3 "cone-tainers" to a patch of buffalo grass [*Buchloe dactyloides* (Nutt.) Engelm.] that had been invaded by Indian grass (*Sorghastrum nutans* L.) and Illinois bundleflower [*Desmanthus illinoensis* (Michx.) MacM.] (Fig. 3). The plants were placed in a variety of exposures from full sun to partial shade and moderate-full shade (Fig. 4). Supplemental water was applied as needed by a gravity flow drip system at approximately 6 L/application.

Table 1. Seed yield per pod.

Accession Number	Patch No.	Clean Seeds No.	Clean Seed Wt. (g)
9050191	92	51	0.36
9050192	129	54	0.32
9050193	144	30	0.16
9050194	158	63	0.41

RESULTS AND DISCUSSION

Time Zero Planting

There was difficulty in keeping the filter paper moist in the petri dishes of the time zero plantings. The moisture tended to collect on the lids of the dishes. After three weeks in the germinator, 1/2 of the seeds were transferred to separate petri dishes lined with moist blotters. The temperature was adjusted up 2°C to bring the temperature more in line with the planned level of 20/24°C. The drying out of the substrate continued. After five days, the seed lots were reconsolidated into plastic boxes on top of moist blotters. No germination was observed in the time zero plantings following 6 weeks at 20/24°C. These plantings were then placed in the refrigerator for a stratification (3-4°C) period.

Cold-moist Stratified Seed

Ten seed units of each seed lot were taken from cold-moist stratification at 6 weeks and placed in the germinators (Table 2). The first germinating seed units were observed 3 days later. By the 4th day 80% germination was observed in the 20/24°C germinator.

Seed units in the 10/30°C germinator were much slower to germinate (Fig. 2). The first seed unit germinated at 5 days and 70% germination occurred at the end of 11 days for seed lot no. 158 and 10% germination for seed lot no. 129. Seed lots no. 144 and no. 92 (Fig. 5) completed germination at 2 and 4 days at 90 and 100%, respectively. The seedlings in the 20/24°C germinator appeared to be more vigorous than those in the 10/30°C germinator. All seedlings appeared to be spindly with thread-like stems and great distances between the nodes. The leaves were very narrow, and the seedlings appeared to be quite frail (Fig. 6).

The initial seedlings were transplanted at 8 days to 10.2 cm^3 "cone-tainers" and placed on the bottom shelf in the germinator. The seedlings continued to display a spindly appearance. After about one week, the cool white light tubes were replaced with grow light tubes. Whether the change in light intensity improved the sturdiness of the seedlings was difficult to determine. After several weeks, the seedlings were transferred to the greenhouse where no change in growth form was noted.

The majority of the seeds placed in the 20/24°C germinator germinated within 3 days. It generally took 1 1/2 to 3 1/2 weeks to obtain similar results in the 10/30°C germinator. The best overall results were obtained at 20/24°C (Table 3). Testing of the 20/30°C environment was not sufficient to draw any conclusions. However, the only lot (92) tested in the 20/30°C germinator was successful.

Some plantings were made directly in the greenhouse to see what effect light intensity had on seedling morphology. The seedlings appeared to have about the same growth form as the earlier seedlings. The main stem was still thread-like and the leaves were very fine and narrow. Germination was poor for two of the three seed lots in the greenhouse environment.

Non-germinating seeds from 4 plots were checked for viability using a 0.1% 2,3,5-triphenyl tetrazolium

Table 2. Planting schedule for Mead's milkweed. Weeks of pre-chill are indicated beneath the temperatures.

Patch/Seed Lot No.	Diurnal Growth Chamber								Greenhouse	
	20/24°C				10/30°C			20/30°C	20/30°C	
	0	6	8	10	6	8	10	12	10	12
92	X	X	X					X	X	
129	X				X	X	X		X	
144		X	X	X						
158	X		X	X	X	X	X			
Miscellaneous[a]										X

[a]Eight seed units

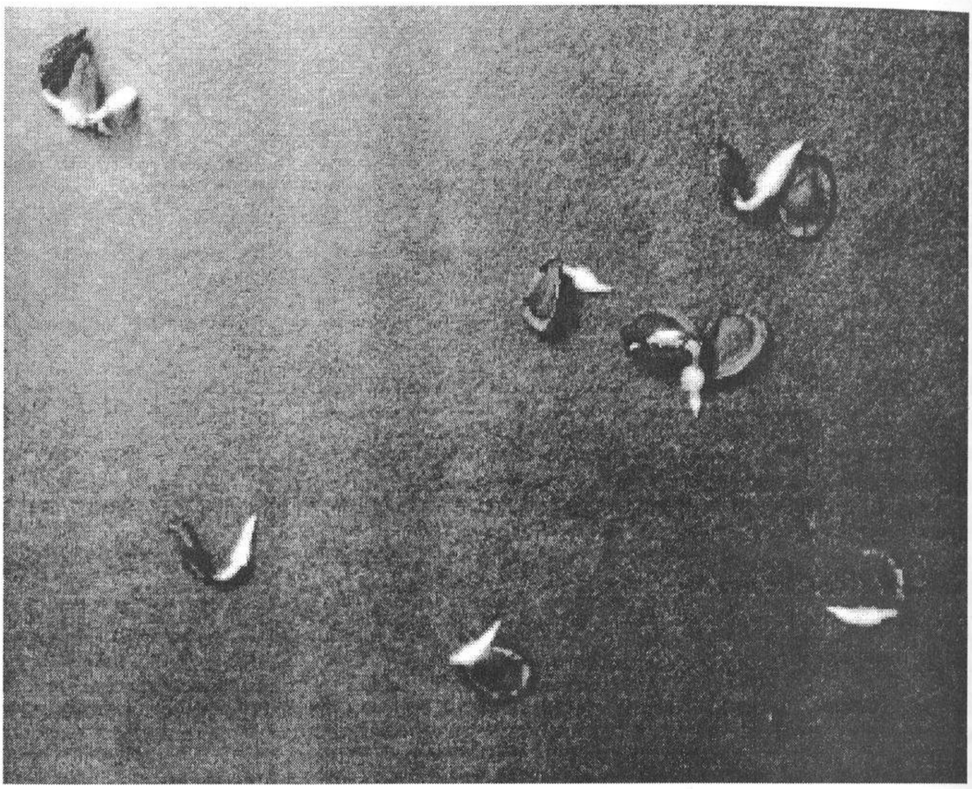

Fig. 2. Mead's milkweed seedlings, germinated at 10/30°C (16h/8h), attained 80% germination on day-4 following an 8 week stratification period, photograph taken on day-6.

Fig. 3. Mead's milkweed transplanted (arrow) to a patch of buffalo grass on the Plant Materials Center near Manhattan, Kansas.

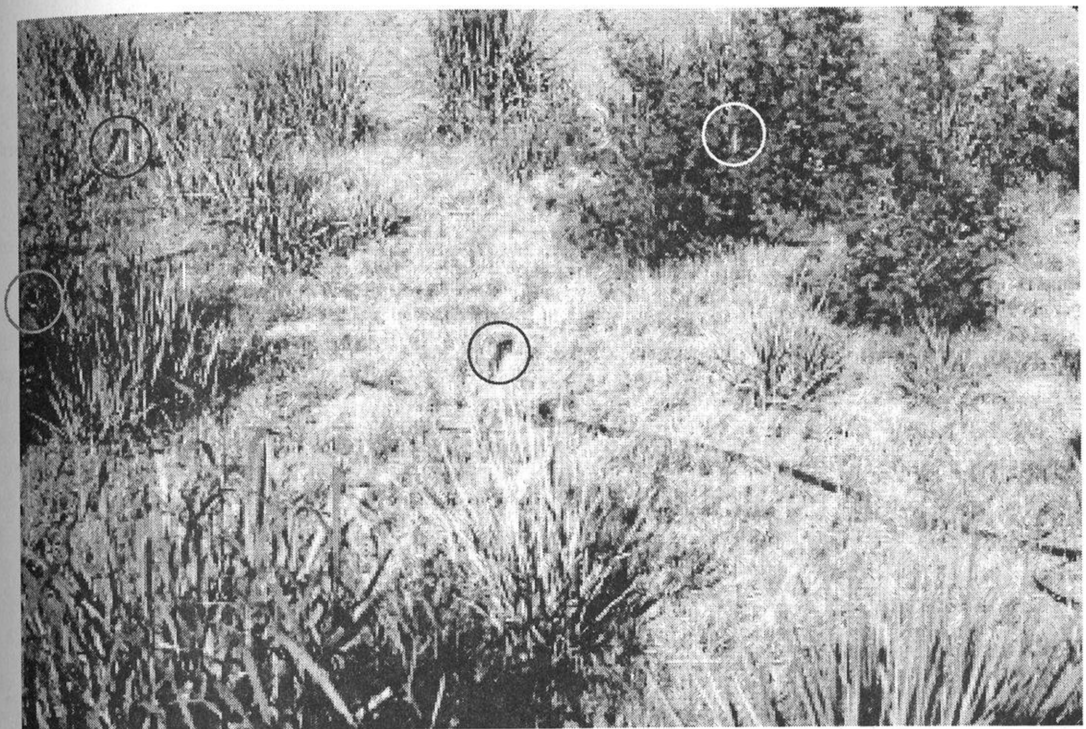

Fig. 4. Buffalo grass patch invaded by Indian grass and Illinois bundleflower, where 7 Mead's milkweed seedlings were transplanted to various exposures. Flags (circled) mark milkweed locations.

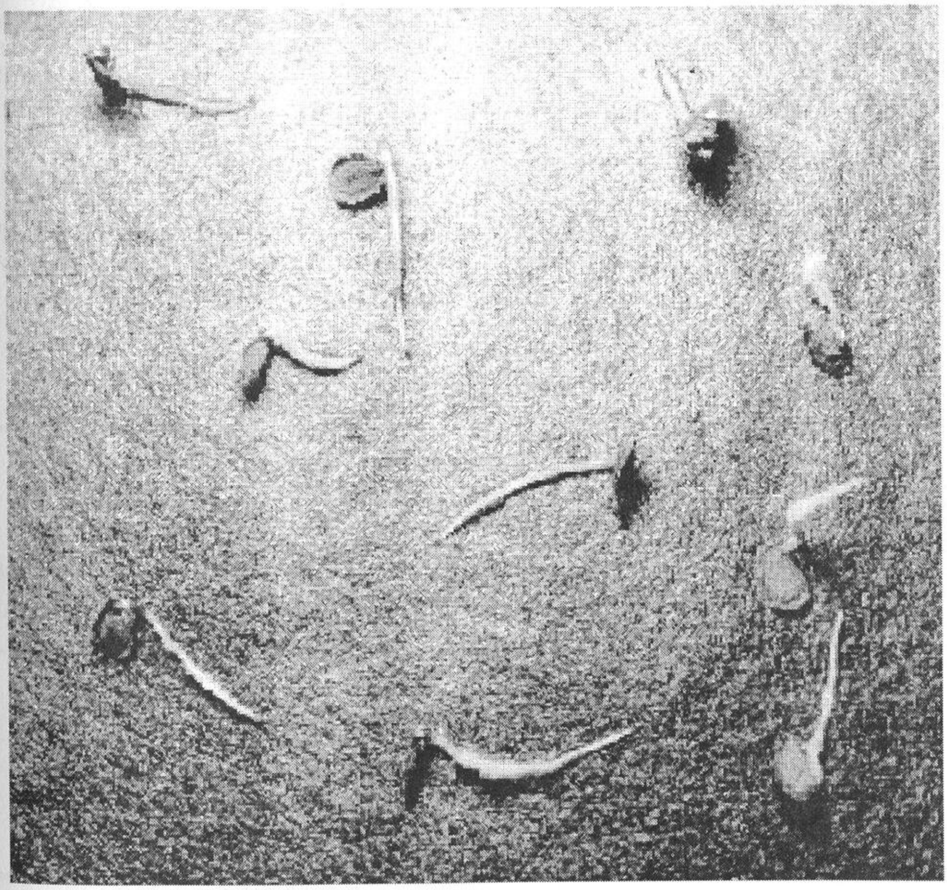

Fig. 5. All 10 Mead's milkweed seeds, germinated at 20/24°C (16h/8h), by day-4. The seedlings were more elongated than those in Figure 2 on day-6.

solution. Out of six seeds tested, 83.3% were viable. Since the non-germinating seeds from the 10/30°C germinator were viable, it was decided to return these plots (with a number of non-germinating seeds) to the 3-4°C refrigerator for an additional stratification period. Two plots were then placed in the 20/24°C germinator after 4 weeks additional stratification time. The result was 100% germination for both plots, Table 4.

Transplant Success

Transplant success from the germination boxes to cone-tainers was very good. One-hundred and two seedlings were potted in the 10.2 cm^3 cone-tainers, with a transplant success rate greater than 95%.

The first transplants were repotted to 25.4 cm^3 cone-tainers at 11 weeks. Transplant success was good with few losses. The shoot was broken off one plant below the soil level during transplanting. It regenerated a new shoot from the thick tap root (Fig. 7) in about a week. In a second case the shoot of two plants died following transplanting. Both plants regenerated a shoot. Fifty-one of these seedlings were repotted to 25.4 cm^3 cone-tainers with a success rate greater than 96%. After a frost, the seedlings were taken to a cooler where they were kept dormant until spring.

Field Establishment

Most of the plants that were established in the field had senesced by late August.

SUMMARY

Four Mead's milkweed pods were harvested in 1996 yielding 198 seeds. Initial germination trials with 6, 8, 10, and 12-week stratification periods, and 3 temperature regimes, were successful.

The 20/24°C temperature regime provided the quickest and most complete germinations. The 10/30°C temperature regime was slower and not as successful. Seedlings from the 10/30°C temperature regime were less elongate than comparable seedlings in the 20/24°C and 20/30°C temperature regimes.

Seedlings were successfully transplanted and established in "cone-tainers". Transplanting the seedlings to larger cones was 96% successful. Transplants established in the buffalo grass patch were also successful but most of them had senesced by late August.

THE NEXT STEP

Seedlings will be established in the field in the spring 1998. Colonies of Mead's milkweed will be established in the 'Salac Prairie', an artificial prairie on the Plant Materials Center, near Manhattan, Kansas. Colonies will also be established as monocultures in a clean tilled situation. The purpose of the colonies will be for seed increase. The seed that is produced will be used for further research. Shorter stratification times need to be tested. Some seed will be used to grow out plants for reestablishment on the Kansas Ecological Reserve.

Future work will also involve the Nature Conservancy land in Anderson County, Kansas. Seed collected from that site will be used for research and reestablishing the species on the site.

Table 3. Percent germination for Mead's milkweed in growth chamber and greenhouse trials. Weeks of pre-chill are indicated beneath the temperatures.

	Diurnal Growth Chamber								Greenhouse		
	20/24ºC				10/30ºC			20/30ºC	20/30ºC		Total %
Patch/Seed Lot No.	0	6	8	10	6	8	10	12	10	12	Germination All Trials[a]
92	0	100	90					90	40		80
129	0				10	10	0		20		10
144		90	100	100							97
158					70	80	70				82
Miscellaneous[b]										87.5	87.5

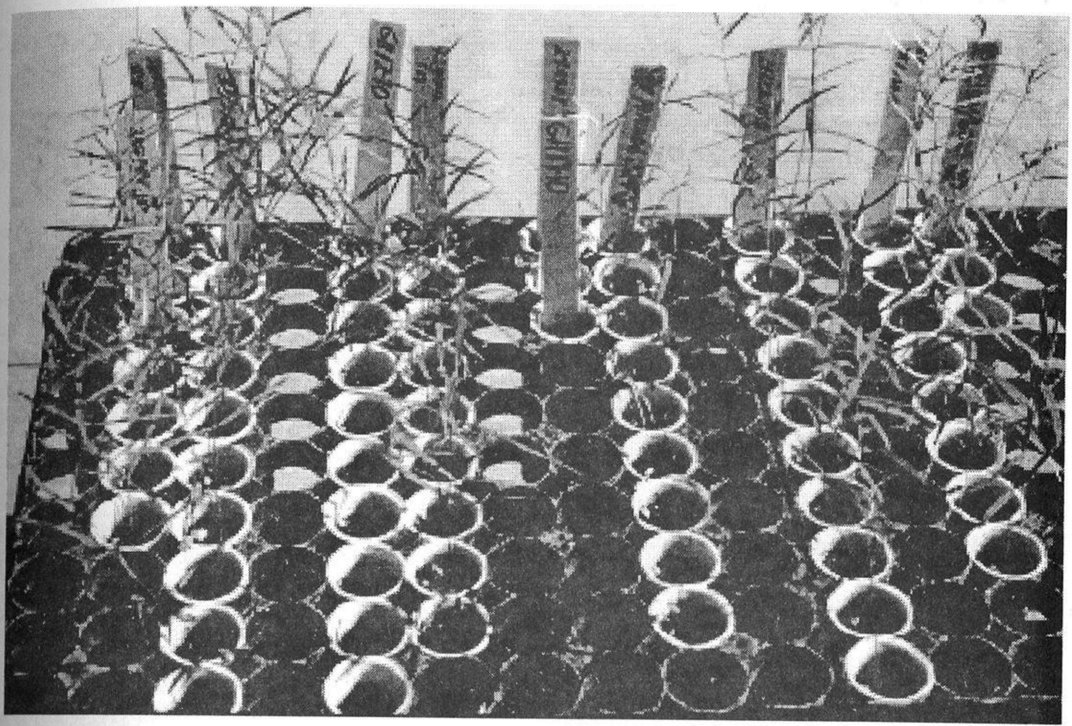

Fig. 6. Mead's milkweed transplants in 10.2 cm^3 Ray Leach cone-tainers containing PRO-Mix BX soilless mix. Note the thin-slender appearance of the seedlings.

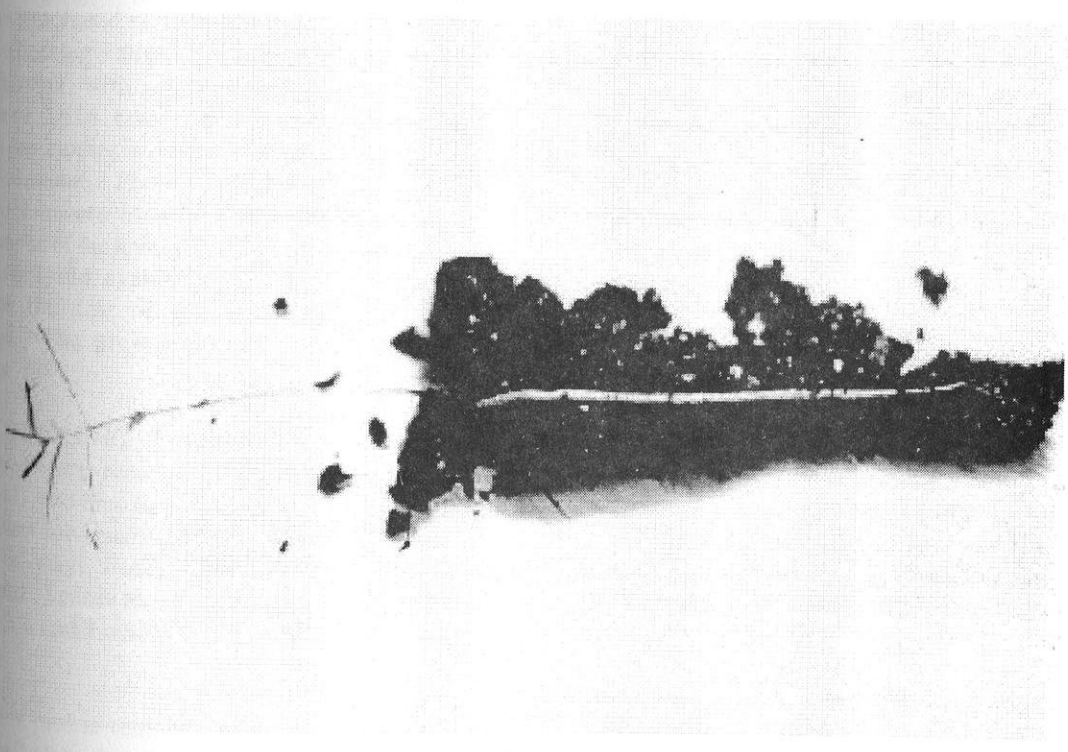

Fig. 7. Fleshy taproot of a Mead's milkweed seedling.

Table 4. Percent germination of Mead's milkweed following 4 weeks additional stratification time (Second Trial).

	Original Trial	Second Trial	
Seed Lot No.	% Germ 10/30ºC	Number of Seeds	% Germ 20/24ºC
129	10	9	100
158	70	3	100

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DAIRY GOATS AS TOOLS FOR CONTROLLING WOODY VEGETATION ON PRAIRIE REMNANTS

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Abstract: A combination of factors led to the exploration of using browsing animals for prairie management. With residential and commercial development encroaching upon many of the typically small prairie remnants of Northwest Illinois, and research showing the undesirability of frequent burning relative to some insect and small mammal populations, fire is becoming a less available tool. Additionally, dense brush such as on buffer areas usually won't carry a fire and needs some type of mechanized or human-powered intervention. Volunteers can be difficult to find, and public and volunteer objections to herbicide use are sometimes made. Therefore, another brush control option was desired.

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Key words: brush control, browsing management, browsing pressure, *Capra hircus*, herd containment, prairie maintenance.

In 1992 a project was begun to assess the feasibility of using a domestic browser, in this case dairy goats (*Capra hircus*), to control brush on prairie remnants in northwest Illinois. Questions needing answers were in the areas of brush control, negative effects on native herbaceous vegetation, herd containment, herd care, and system cost. A small, non-breeding herd (6 wethers purchased as kids) was used in five treatment plots reflecting various browsing pressures and in combination with other standard brush control measures on a brushy power line right-of-way. Follow-up studies were done on two local degraded prairie remnants. Photo points and observations were used to measure browsing effectiveness and plant preferences of the animals. Different fencing methods were used and evaluated. Records were kept to monitor the cost of the project and care of the animals. The project entered its seventh year in summer 1998.

ESTABLISHING A HERD

On projects mostly in western states, both large and small, and breeding and non-breeding herds have been used for brush control, primarily for clearing rights-of-way, Forest Service burn lines and rangeland. I chose to purchase six dairy kid goats and establish a small non-breeding herd for the following reasons:

1. Most prairie remnants in northwest Illinois are small (less than 5 acres), so a small herd would be better suited to those areas.
2. Unwanted buck dairy kids are cheap (average $30/kid) and plentiful in our area. Doe kids are considerably more expensive.
3. The study area often contained thorny brush that would have damaged the udders of does.
4. Wethers (castrated bucks) are the lowest maintenance goats.
5. I had sufficient land to maintain a small herd.
6. Purchasing kids allowed me to bond with the animals, making for easier training.
7. I wanted to train only one set of animals.

NOTE: It must be emphasized that the observations and experiences from this project apply only to this herd. Variation could be expected with differences in herd composition, goat breed, local climate, and local flora.

VARIABLE BROWSING PRESSURES STUDY

Initially the project focused on trying to find an optimal browsing pressure, one that would set back woody vegetation without excessive damage to herbaceous vegetation, alone or in concert with other prairie management tools. A brushy powerline right-of-way with little native herbaceous vegetation was used for this purpose.

For six years, 1992-1997, the herd browsed in the plots according to the specific browsing pressures indicated in Fig. 1. In addition, two common brush control methods (initial hand removal of brush and burning) were integrated into plots A and F, respectively. Each year browsing began in early June. "Browse to visual maximum" is a judgment call: remove the animals when all or most of the reachable woody vegetation is defoliated, before severe impact (through eating, trampling or digging) on herbaceous vegetation occurs. Goat Browsing Hours (GBH) were recorded for each plot (Table 1).

Results

After 6 years, Plot A (Fig. 1) had the least amount of woody vegetation, with a number of GBHs comparable to the full browse of Plot C (Table 1). Plot F was the next to the least amount, then Plot C, Plot E and finally Plot D with the most. These amounts are apparent visually.

The specific browsing pressures were discontinued in 1998 since the GBHs were leveling off (1995 and 1997 hours were similar) and vegetation composition was static. Browsing in 1998 were done on all plots except the control to visual maximum and targeting certain species such as Japanese Honeysuckle (*Lonicera japonica*) for early season browsing.

Observations

1. The size of a plant and the goats' preference for the plant are the biggest factors in determining how quickly goats can thoroughly browse an area.
2. Smaller trees and shrubs (less than 2 m tall) are preferred by goats.
3. Small trees will be killed or set back from being defoliated. Some girdling is done on larger trees, especially cherries and plums (*Prunus* spp.). However, goats generally will not girdle trees, unless there is little browse and/or low herbaceous vegetation.
4. When goats have browsed most of their preferred plants in an area, they put a lot of pressure on fences (other than electric).
5. Goats more readily will browse less preferred plants earlier in the browsing season (e.g. Japanese honeysuckle that would leaf out in April is preferred over the same honeysuckle in June when more preferred plants are available).
6. Goats generally prefer fully leafed out woody vegetation.
7. In addition to leaves, goats will eat twigs and small branches up to the diameter of a pencil.
8. Most often goats move from plant to plant, eating a bit from each one, rather than working steadily on one plant until it is defoliated.
9. Although goats prefer woody vegetation, they will eat some herbaceous vegetation. The species preferences and long-term impact on those species needs further study.
10. Goats prefer not to eat trampled vegetation.

Table 1. Goat browsing hours[a] per plot per year.

Plot	1992	1993	1994	1995	1996	1997
A	0.0[b]	160.5	148.5	64.5	37.5	34.5
B	0.0	0.0	0.0	0.0	0.0	0.0
C[c]	321.0	136.5	82.5	25.5	30.0	27.0
D	339.0	136.5	82.5	25.5	30.0	27.0
E	975.0	517.5	343.5	85.5	112.5	75.0
F	829.5	511.5	312.0	85.5	112.5	79.5
# of Browsings	2	2	3	3	2	2

[a] Goat Browsing Hour is one goat browsing for one hour.

[b] Plot not ready for use in 1992.

[c] Plots C and D should have the same number of hours. Plots E and F should have the same number of hours (refer to illustration of plot sizes and treatments). Where not the case, goats were inadvertently left in plot over time limit or in the case of Plot F in 1992, goats were removed early because there was no reachable woody vegetation remaining in the plot.

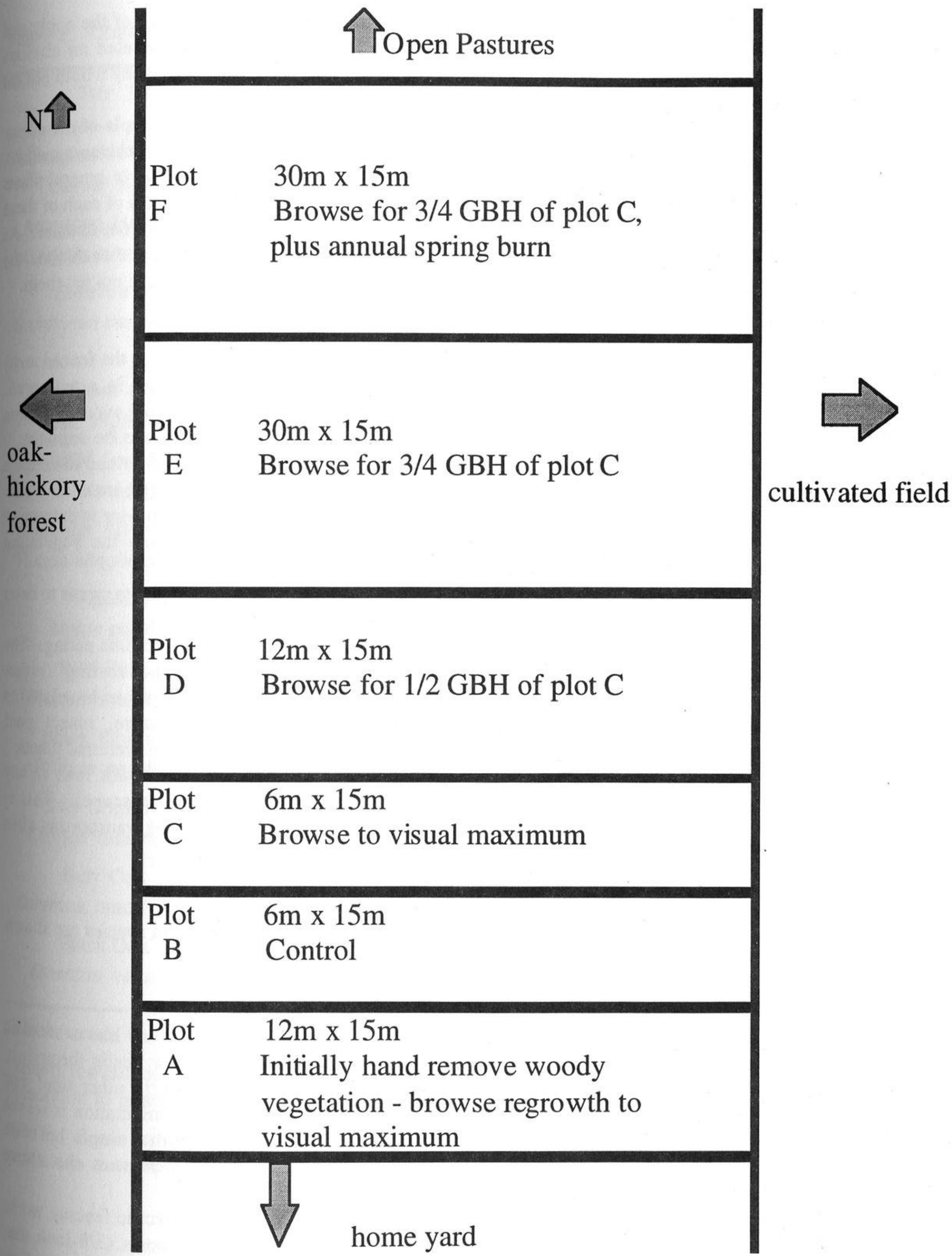

Fig. 1. Powerline right-of-way plot sizes and treatments.

PRAIRIE STUDIES

The next step in the project was to take the herd to local degraded prairies to find out what impact they had on both native herbaceous vegetation and additional species of woody vegetation.

Two sites have been used thus far: the Dufford Site and the Clear Creek Site. The goats were transported to the sites in a trailer, confined to the site with electric fence and allowed to browse for approximately 7-9 hours (42-54 GBH) per day. The browsing management strategy for each site thus far has been to browse to visual maximum at the height of the growing season and browse regrowth later in the summer, for a total of 2-3 browsing periods. Observation journals were kept and photos taken.

Dufford Site

The Dufford Site (56 m x 33 m) is on a badly degraded hill prairie where the main invaders are smooth sumac (*Rhus glabra*), wild parsnip (*Pastinaca sativa*), and quack grass (*Agropyron repens*). Various woody shrubs from the edge of a woodland have begun to invade. There was not much quantity or diversity of prairie species on this site. The site was browsed twice in the summer of 1996, 35 hours (210 GBHs) in early July and 17 hours (102 GBHs) in mid- August.

The goats completely stripped the woody vegetation along the woodland edge but would not eat the sumac and would eat only the full leaves of second year parsnip.

The site needs further evaluation to determine if goats will eat younger sumac and/or parsnip. Time constraints prevented further study of this site in 1997 and 1998.

Clear Creek Site

The Clear Creek Site (35 m x 23 m) is in a sandy prairie remnant. The dominant invader is multiflora rose (*Rosa multiflora*) in enormous clumps and the secondary invader is common dewberry (*Rubus flagellaris*). There are also a few small black cherry (*Prunus serotina*), red cedar (*Juniperus virginiana*), an apple tree (*Malus pumila*), and a large Osage orange (*Maclura pomifera*). This site has a considerable quantity and diversity of prairie species.

The site was first browsed in summer 1998, with the first browsing period of 6 days scattered in mid-June and early July totaling 43 hours (258 GBHs). A second browsing period will take place in mid-August, 1998.

The goats ate into the rose clumps until the dead vegetation prevented a further reach. They ate a lot of the upper dewberry leaves, as much of the apple and cherry as they could reach, and created an obvious browse line on the Osage orange. They would not eat the red cedar.

They eventually ate all but a couple of the dozen or so flowering purple coneflower (*Echinacea pallida*), and several rough blazing star (*Liatris aspera*) plants with flower buds. Several individuals of each of these species were sprayed with a tea of goat manure. As long as the plants were sprayed once each time the goats were at the site, the animals did not eat them.

Observations

1. Herdsperson should stay (outside the fenced area) with the herd for the first day in a new area. Thereafter the herdsperson should make a decision based on potential disturbances to the animals.
2. Sometimes goats will paw the ground to create a bare area or enlarge an existing bare area. More follow-up is needed on this behavior to determine how often they do it and how the vegetation recovers.
3. Goat manure tea sprayed on plants seems to deter the goats.
4. Goats do not spend all of their time eating. The amount of time they spend resting (either standing or lying down) appears to be related to chewing cuds, air temperature, insect pest populations, and availability of preferred plants.
5. Goat droppings appear to contain few, if any seeds (as inspected with microscope). This is good news relative to avoiding transporting alien species onto prairie remnants.

PLANT PREFERENCES

Preferences for different plant species are shown in Tables 2 and 3.

FENCING

Goats are hard on fencing. They like to stand on it, rub against it, and push their heads through it. The browse is always greener on the other side! For more permanent areas, a good combination is woven wire or welded steel panels with a single hot wire strung at about 24 inches to prevent the above behaviors.

For prairie areas, portable electric fencing works well. Use 48-inch fiberglass posts (3/8-inch diameter) and two wires (16 or 17 gauge steel or aluminum) at 18 inches and 28 inches. Steel corner posts (also 3/8-inch diameter) are used to provide more support. Only one steel T-post is used to support the solar fencer. With this method you get

Table 2. Observed woody plant[a] preferences.

Tier 1	Tier 2	Tier 3	Won't Eat
Shagbark Hickory *Carya ovata*	Osage Orange *Maclura pomifera*	Japanese Honeysuckle *Lonicera japonica*	Smooth Sumac *Rhus glabra*
American Hazelnut *Corylus americana*	Black Raspberry *Rubus occidentalis*	White Mulberry *Morus alba*	Red Cedar *Juniperus virginiana*
Elderberry *Sambucus canadensis*	Prickly Ash *Xanthoxylum americanum*	Virginia Creeper *Parthenocissus quinquefolia*	
Multiflora Rose *Rosa multiflora*	Box Elder *Acer negundo*	Eastern Cottonwood *Populus deltoides*	
Wild Grape *Vitis spp*	Wafer Ash *Ptelea trifoliata*	Poison Ivy *Rhus radicans*	
Common Blackberry *Rubus allegheniensis*	Black Willow *Salix nigra*		
Apple *Malus pumila*	Common Dewberry *Rubus flagellaris*		
Wild Plum *Prunus americana*			
Black Cherry[b] *Prunus serotina*			
Gray Dogwood *Cornus racemosa*			
Burr Oak *Quercus macrocarpa*			
Black Oak *Quercus velutina*			

[a]Plant names in this table follow nomenclature given in Swink & Wilhelm (1994).

[b]Wilted leaves of this species are poisonous to goats. Be aware of this and other plants that are poisonous to goats.

NOTE: Some species' palatability appears to change with the seasons. Also, this herd has not had access to a number of woody species including most conifers, buckthorn, and black locust.

Table 3. Observed herbaceous plant[a] preferences.

Tier 1	Tier 2	Tier 3	Won't Eat
Wild Carrot *Daucus carota*	Stiff Goldenrod *Solidago rigida*	Rough Blazing Star *Liatris aspera*	Virginia Mt. Mint *Pycnanthemum virginianum*
Cup Plant *Silphium perfoliatum*	Yellow Coneflower *Ratibida pinnata*	Yellow Sweet Clover *Melilotus officinalis*	Hoary Vervain *Verbena stricta*
Rosin Weed *Silphium integrifolium*	Purple Coneflower *Echinacea pallida*	Scribner's Panic Grass *Panicum oligosanthes* var. *scribnerianum*	Common Grass-Leaved Goldenrod *Solidago Graminifolia*
Quack Grass *Agropyron repens*	Giant Ragweed *Ambrosia trifida*	Canada Thistle *Cirsium arvense*	Small Skullcap *Scutellaria parvula*
Smooth Brome *Bromus inermis*	Common Ragweed *Ambrosia artemisiifolia*		False Boneset *Kuhnia eupatorioides corymbulosa*
Orchard Grass *Dactylis glomerata*	Red Clover *Trifolium pratense*		Whorled Milkweed *Asclepias verticillata*
Canada Goldenrod *Solidago canadensis*	Wild Parsnip (leaves only of 2nd yr. plants) *Pastinaca sativa*		Lance-Leaved Loosestrife *Lysimachia lanceolata*
Reed Canary Grass *Phalaris arundinacea*	Bull Thistle *Cirsium vulgare*		Yarrow *Achillea millefolium*
Tall Nettle *Urtica procera*	Garlic Mustard *Alliaria petiolata*		
	Big Bluestem *Andropogon gerardii*		

[a]Plant names in this table follow nomenclature given in Swink & Wilhelm (1994).

NOTE: There are many herbaceous species, especially native ones, to which this herd did not have access.

good containment with very little disturbance to the prairie, and little labor. Two people can completely fence a 35-m x 23-m area in two hours, including trimming vegetation directly beneath the wires.

At the beginning of the project, I thought I would be able to herd the goats in the absence of fencing. While this might have some narrow applications, for the most part even the most well-trained goat will prefer a really good plant over the voice of the herdsperson.

ANIMAL CARE

As domestic animals go, goats have few special needs and are relatively free from disease. Any number of books are available on raising goat kids. After weaning, kids still need a grain ration along with forage and water. After age 5, forage and water will be sufficient.

Goats need a dry, draft-free, well-ventilated shelter. I used a discarded duck dwelling and added a small structure to it for hay and straw storage. The more time goats spend in sun and fresh air, the fewer health problems they will have. In drier areas of the U.S. minimal shelters seem to work fine.

Other than feeding, watering and bedding the herd, the only other regular chores are hoof-trimming and worming. Depending upon where you live, these jobs will be done more or less often.

My herd is wormed frequently (6 times/year) to help avoid the internal parasite *Paralaphostrongylus tenuis*, or brainworm, which two of my animals contracted. If not detected early, the parasite can cause permanent injury to the spinal cord and eventually death. This parasite is more prevalent east of the Mississippi and needs land snails and white-tailed deer to complete its life cycle.

COSTS

Goat maintenance costs can vary depending upon access to pasture/browse, animal health and the price of hay and straw. Post-weaning, on average I spent $106 per animal per year. Hay and straw comprise 70% of this cost, with minerals, feed, and medical care included in the other 30%. Some years I spend much more on medical care, e.g. years when *P. tenuis* was diagnosed and treated (see Animal Care).

Portable fencing costs are a one-time expense. My solar fencer cost $150 but can be moved from site to site. Fencing materials for the Clear Creek Site were about $45 and can be reused at other sites.

Shelter and hauling costs can vary dramatically depending on what materials you already have or can borrow. My hay and straw storage addition to the goats' shelter (which was free) ran about $1000. I borrow a pickup truck to pull a trailer which cost around $1500. The trailer is also used to haul hay and straw. Permanent fencing attached to the shelter will vary greatly depending upon which materials you use and if you scrounge them or buy them new.

Grants, in-kind donations, and volunteer labor all could greatly reduce the cost of maintaining a herd.

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ATV FOAM SLIP–ON UNIT FOR PRESCRIBED BURNING

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Abstract: Our efforts to develop a Compressed Air Foam (CAF) slip–on unit small enough to be used on an all terrain vehicle (ATV) have evolved to our current slip–on unit. We have abandoned the compressed air because of difficulties with the plumbing, weight , user–unfriendly valves and gages, and corrosion in the pump mechanism. The current unit is built from commercially available parts, simple to use and low maintenance. The foam produced a more effective wet line than one made with water alone.

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Key words: all terrain vehicle, CAF, Compressed Air Foam, prairie fire, prescribed burn.

The Minnesota Department of Natural Resources Scientific and Natural Areas (SNA) Program makes every effort to use management techniques and equipment that have a low impact on the natural features being protected in the sites. For this reason, burn breaks in prairie areas are mowed rather than disked. When vehicles are required, an all–terrain vehicle (ATV) is used instead of a truck, because a heavier truck will compact soil, might leave ruts and will do more damage to vegetation. An ATV with a small slip–on pump unit provides a light–weight vehicle to transport water for burning and mop up and to apply an effective wet line along mowed breaks.

Fire retardant foam generated using air compressors has been used in structural and forest fire suppression for many years. It is an effective barrier to fire when applied to fuels before burning and smothers flames when sprayed on burning fuels. Foam is more effective than water alone. It breaks surface tension that make many fuels difficult to wet down with plain water. Because of its structure and chemistry even as it dries, foam acts as a barrier to flames. Consequently less water is required to achieve the same results. This is an advantage on many of our natural areas where water availability may be limited.

The First Attempt

In 1990 the SNA Program developed a mini compressed–air foam (CAF) slip–on spray unit for use on an ATV (Fig. 1). The first applications of this piece of equipment were very promising, but in the long run, it was not dependable and failed mechanically.

The mini CAF was built to fit the bed of the Polaris® Big Boss 4 X 6. This ATV has a rather high center of gravity, but the slip–on unit profile was low resulting in a relatively stable unit for most terrain. Mounting the slip–on in the ATV was made somewhat inconvenient because the water tank was independent of the pump unit.

The foam line produced by the mini CAF could be adjusted for widths up to 0.5 m (18 in) (Fig. 2). A range of foam density or structure from froth to "shaving cream" was possible. The foam could be laid down by the ATV operator while driving or by a second person. This was convenient for foam lining the break on hills not safely negotiable by the ATV. The hose allowed for foaming down hazards near the break pre–burn and for dowsing difficult to reach snags during mop up.

The foam concentrate entered the system before the pump. When not spraying, water was by passed into the tank and foam continued to be injected into the system. This resulted in a tank full of increasingly concentrated foam mix. When replenishing the water level in the tank, suds would spill over onto the ATV, slip–on and people. Pumps burned out repeatedly when they became clogged with thickened chemical even though the pump was backwashed at the end of each day. The unit vibrated a lot and many of the vast number of nuts and bolts would jiggle free.

The mini–CAF unit combined a 3–kW (4–horsepower) engine to drive a roller pump capable of 0.3 L/sec (4.9 gal/min) at 7 kg/cm^2 (100 lb/in^2) and an air compressor capable of producing 472 mL/sec (2 ft^3/min) free air at 7 kg/cm^2 (100 lb/in^2).

Fig. 1. The first attempt at adding Compressed Air Foam (CAF) to an ATV slip-on resulted in a low profile unit but was a nightmare of plumbing and corrosion.

Fig. 2. Foam-lining with mini-CAF : Compressed air creates the most effective foam, but the complex plumbing on this unit failed mechanically.

The slip–on unit included a 200-L (50–gal) water tank made from 13-mm (0.5–inch) plastic plate, a 8-L (2–gal) container for foam concentrate, a manual hose reel with 15 m (50 feet) of high pressure hose and spray gun. In addition to shut off valves for water, air and foam, there were check valves, pressure relief valves, pressure gauges for air and water, a injector/proportioner to adjust the concentration of foam mix and pet cocks for bleeding the air lines (of water) and water lines (of air). There was a lot of convoluted plumbing and expanded metal cage around the moving parts of the compressor making accessibility to valves, grease zerks, oil dip stick and fill tubes difficult.

Perhaps someone with time and a of small pumps and compressors could improve on this idea. The air compressor is the key to the most effective, structurally superior foam. We've abandoned the aggravations of this unit and put together the following system which achieves almost the same results in producing a foam or straight water spray.

Second Attempt: MWC Injection Unit

The Minnesota Wanner Company (MWC) is located in Minneapolis. MWC worked closely with us to develop our current ATV foam slip–on unit (Fig. 3). An aluminum frame combines the 220-L (55–gal) polyethylene water tank and pump assembly into a single integral unit. This allows easy installation in the bed of the ATV. The components are standard items used in agricultural spray equipment. The 4–cylinder piston pump with adjustable pressure control and pressure gauge is powered by a 3.7–kW (5–horsepower) engine. It can produce up to 0.6-L/sec (10 gal/min) and 26 kg/cm^2 (375 lb/in^2). Foam enters the water line after the pump with an adjustable inductor. A manual hose reel carrying 30 m (100 ft) of flame resistant hose is mounted over the pump and foam concentrate container. An in–line aerator introduces air into the mix just prior to the spray nozzle to produce a foam line.

The Wanner slip–on is a much simpler unit and is more user friendly (Fig. 4). This is important when there are potentially many different operators. Introducing the foam into the system after the pump eliminates the potential of fouling the pump mechanism and water tank with caustic chemical.

The arrangement of the slip–on components, water tank, pump and hose reel, is largely determined by the size and shape of the ATV cargo area. On the Polaris 6 X 6, the result is a fairly high profile and reduced stability. The center of gravity on the Polaris is relatively low and this counters the high profile of the slip–on to some extent. The spray pattern is about 0.3 m (12 in) wide with the nozzle mounted about 0.6 m (2 ft) above the ground. A single valve is used to select water alone or foam. The concentration of foam is determined by a needle valve adjustment in the inductor. The foam line is frothy and superior to water alone, but it is not the thick, effective foam that was produced with compressed air.

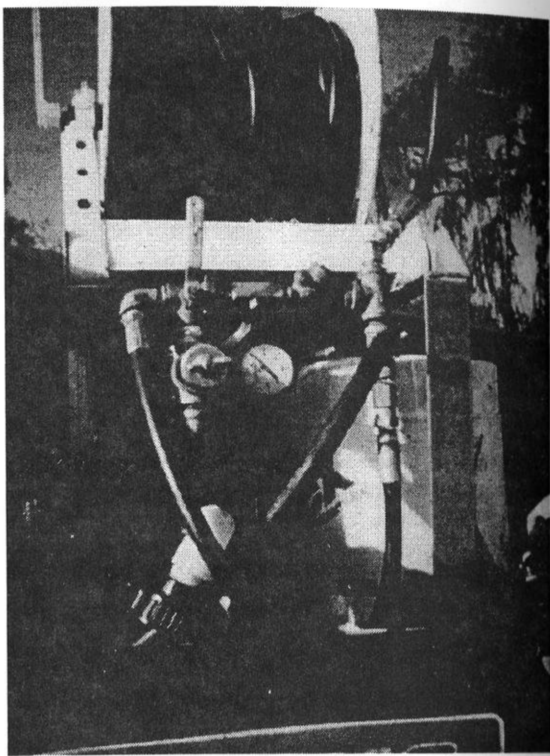

Fig. 3. Minnesota Wanner Co. Foam induction unit.

Comparisons

Mini CAF Positives.—The mini CAF produced excellent foam that inhibited and smothered fire when laying a fire line, protecting fire hazards (brush piles, signs, fence posts and other objects that were not to be burned) and in mop up. The slip–on had a low profile that kept the center of gravity low.

Mini CAF Negatives.—The compressor added weight that had to be compensated for by reducing the amount of water that could be carried. The contrived plumbing and engineering to control the water pressure, air pressure and foam concentration resulted in a complex arrangement of valves, gauges, and fittings that was difficult to operate and maintain. The presence of chemical in the pump and water tank

Fig. 4. Foam lines often allow the crew to work at a distance away from the intense heat and smoke.

damaged the pump and resulted in a messy and dangerous slick on equipment.

MWC Injection Unit Positives.—The new unit is "user friendly" and reliable. The aluminum frame makes mounting in the ATV quick and easy. The lighter pump assembly permits a greater water capacity within load limits. Components are readily available and replaceable. The plumbing and engineering are simple and straight forward making trouble shooting manageable. The more powerful pump has a greater range which is an advantage especially in mop up.

MWC Injection Unit Negatives.—Although the quality and effectiveness of the foam is better than the results of the common practice of adding dish soap to the water tank, it is not as good as the foam created by a compressed air system.

PLATEAU™ HERBICIDE FOR MIXED PRAIRIE ESTABLISHMENT

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Abstract: The use of the herbicide PLATEAU™ is shown to work in establishing prairie grasses and forbs in experimental plots in south central Ohio. Of the rates and application timings tested, 0.094 to 0.125 lbs ae/acre of PLATEAU herbicide applied early post-emergence gave the greatest benefits for prairie establishment in southern Ohio. These treatments resulted in the greatest number of tolerant forb and grass species, while providing adequate weed control. This program would allow a manager to choose from 7 native warm season grasses and 26 different forbs, including all the legume species tested.

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Key words: American Cyanamid Company, prairie restoration.

Establishment of native prairie grasses and forbs is often compromised due to intense competition from aggressive annual weeds. Such plantings can take years to establish using traditional methods, and in some cases, result in complete stand loss. The use of a herbicide during establishment can prevent or reduce weed interference with desirable seedlings, enabling them to quickly become established perennials. Once established, proper prairie management should ensure a long lived, biodiversed prairie. In previous trials, several herbicides were screened on key prairie species and PLATEAU herbicide provided the best results to achieve this goal.

The objectives of these trials were to determine the tolerance to PLATEAU of seedling native warm season grasses and various forbs and PLATEAU's efficacy on common competitive annual weeds. Establishment of these species, flowering ability, weed spectrum and longevity of control were the primary focus of the evaluation.

Table 1. Background data on site preparation for native warm season grasses in spring 1996.

Item	Comments
Fertilized	27 March using 150-40-60/acre
Land preparation	Existing vegetation (perennial grasses and legumes) was treated on 1 April with Finale herbicide. Plowed on 7 April, field cultivated 18 May.
Soil type	Loam (38% sand, 44% silt, 18% clay) O.M. 2.8, pH 7.4, CEC 11.5
Plot size	16 x 10 ft (note: grass species were planted in 16-ft strips east/west, herbicide treatments were applied north/south across all grasses.)
Planting	19 May. Seed was drilled using a Truax no-till drill with a fluffy seed box, at the depth of 0.0 in to 0.12 in at the recommended rate. Eastern gamma - planted with a no-till corn planter at 25,000 seeds/acre, 15-in rows.
Application	11002LP flat fan / 35 psi / 29 GPA
Early Postemergence	30 May
Weather: Air temp.	60°F
soil temp.	60°F
soil moisture	wet

soil moisture wet

MATERIALS AND METHODS

Native Warm Season Grasses

Research was conducted in Frankfort, south central Ohio. The plot area was a productive fescue pasture. Fertilization was not needed for native warm season grass establishment. The pertinent back-ground data are itemized in Table 1.

The grasses involved were: little bluestem (*Andropogon scoparius*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), sideoats gramma (*Bouteloua curtipendula*), blue gramma (*Bouteloua gracilis*), and eastern gamma grass (*Tripsacum dactyloides*).

The chemical treatments used are as follows:

1. PLATEAU 2AS 0.063 lbs ae/acre + Silken 2.5 oz/acre.
2. PLATEAU 2AS 0.063 lbs ae/acre + Sun-it II 2 pts/acre.
3. PLATEAU 2AS 0.094 lbs ae/acre+ Silken 2.5 oz/acre.
4. PLATEAU 2AS 0.094 lbs ae/acre + Sun-it II 2 pts/acre.
5. PLATEAU 2AS 0.125 lbs ae/acre+ Silken 2.5 oz/acre.
6. PLATEAU 2AS 0.125 lbs ae/acre + Sun-it II 2 pts/acre.
7. PLATEAU 2AS 0.156 lbs ae/acre+ Silken 2.5 oz/acre.
8. PLATEAU 2AS 0.156 lbs ae/acre + Sun-it II 2 pts/acre.
9. PLATEAU 2AS 0.188 lbs ae/acre+ Silken 2.5 oz/acre.
10. PLATEAU 2AS 0.188 lbs ae/acre + Sun-it II 2 pts/acre.
11. non-treated check.

Wildflower Species

The pertinent back-ground data are itemized in Table 2. All post-emergence treatments included nonionic surfactant at 0.25% v/v.

The chemical treatments used are as follows:

1. PLATEAU 2AS 0.063 lbs ae/acre.
2. PLATEAU 2AS 0.094 lbs ae/acre.
3. PLATEAU 2AS 0.125 lbs ae/acre.
4. PLATEAU 2AS 0.188 or 0.25 lbs ae/acre.
5. non-treated check.

Table 2. Background data on site preparation for wildflower species in spring 1996. Wildflower species were split into 2 post-emergence trials (early germinators and late germinators) to assure a post application to all species. Postemergence applications would be typically timed to weed size.

Item	Comments		
Fertilized	27 March using 150-40-60/acre.		
Land preparation	rototilled 28 March and 19 April.		
Soil type	Loam (38% sand, 44% silt, 18% clay), O.M. 2.8, pH 7.4, CEC 11.5.		
Plot size	12 x 15 ft, 20 subplots per plot, 3 x 3 ft. (Note: 1 wildflower species per subplot—subplots were not random within a plot, plots were randomized within a trial.		
Planting	21 April. Seed was hand broadcast @10 g/subplot and raked in. Sunflowers were planted 0.5" deep, thinned to12 plants/subplot. Day Lilies were trans-planted, 3/subplot.		
Application	8002 flat fan / 30 psi / 20 GPA .		
	Preemergence	Postemergence	
	21 April	30 May	13 June
Weather: Air temp	64°F	60°F	70°F
humidity	30%	50%	90%
soil temp	68°F	60°F	70°F
soil moisture	moist	moist	saturated

Table 3. Tolerance of native warm season grasses to PLATEAU, applied preemergence to early post-emergence (2-leaf grasses). Letters denote significance within a column using the Duncan's multiple range test at the 0.05 level.

PLATEAU (lbs ae/acre)	adjuvant*	plant stand count (#/m2) 6 months after treatment					(#/plot)
		Little bluestem	Big bluestem	Indian grass	Sideoats Grama	Blue Grama	Eastern Gamma
0.063	Silken	68 a	57 a	83 a	18 a	39 a	6 ab
0.063	Sun-it II	57 a	54 a	83 a	22 a	36 ab	3 c
0.094	Silken	54 a	54 a	75 a	14 ab	25 a-c	4 bc
0.094	Sun-it II	65 a	50 a	75 a	18 a	25 a-c	5 ac
0.125	Silken	65 a	47 a	83 a	11 a-c	43 a	7 a
0.125	Sun-it II	68 a	50 a	75 a	11 a-c	22 a-c	7 a
0.157	Silken	57 a	57 a	72 a	11 a-c	11 bc	4 bc
0.157	Sun-it II	68 a	54 a	79 a	11 a-c	7 c	3 c
0.188	Silken	61 a	54 a	83 a	4 bc	0 c	3 c
0.188	Sun-it II	61 a	57 a	86 a	0 c	0 c	3 c
Non-treated		7 b	7 b	11 b	14 ab	11 bc	0.7 d

Table 4. Percentage of weed control at 14 weeks after treatment with early post emergence application. Surfactants did not differ in weed control and data were combined.

Common Name	Growth stage	PLATEAU (lbs ae/acre)				
		0.063	0.094	0.125	0.157	0.188
Grass						
Barnyard grass	pre -2-leaf	100	100	100	100	100
Giant Foxtail	pre -2-leaf	100	100	100	100	100
Goosegrass	pre - spike	90	90	98	100	100
Johnson-grass Seedling	pre	100	100	100	100	100
Large Crabgrass	pre -2-leaf	90	95	100	100	100
Yellow Foxtail	pre -2-leaf	80	100	100	99	100
Sedge						
Yellow Nutsedge	spike-4-leaf	100	100	100	100	100
Broadleaf						
Biennial Wormwood	pre -rosette	65	80	90	95	95
Common Ragweed	pre	70	90	100	98	100
Jimson Weed	pre	100	100	100	100	100
Lamb's quarters	pre	100	100	100	100	100
Pitted Morningglory	pre	95	100	100	100	100
Redroot Pigweed	pre	100	100	100	100	100
Velvetleaf	pre	100	100	100	100	100

Table 5. Tolerance of forb species to PLATEAU, for prairie grass mixes in terms of percentage injury at 6 weeks after treatment. Injury occurred as stunting, thinning, leaf burn and /or desiccation of the growing point. When one symptom was predominant the type of injury is indicated. Leaf burn and desiccation of the growing point only occurred in post treatments. Numbers in **bold** represent acceptable tolerence.

		PLATEAU (lbs ae/acre)							
		Pre-emergence				Post-emergence			
Common Name	Latin Name	0.063	0.094	0.125	0.25	0.063	0.094	0.125	0.188
Alfalfa	*Medicago sativa*	90	80	95	100	**0**	**0**	**0**	**0**
Annual Phlox	*Phlox drummondii*	**0**	**0**	**0**	**0**	67	100	100	100
Baby-blue-eyes	*Nemophilia menziesii*	100	100	100	100	**0**	35	100	100
Bird's-eye	*Gilia tricolor*	100	100	100	100	**0**	30	50	87
Bishops-weed	*Ammi majus*	100	100	100	100	**20**	48	78	100
Black-eyed Susan	*Rudbeckia hirta*	**8**	**0**	**0**	**12**	**0**	**7**	**15**	**17**
Blanket Flower	*Gaillardia aristata*	66	53	43	87	**0**	**8**	**0**	37
Blue Flax	*Linum perenne*	67	67	83	100	**18**	47	59	59
California Poppy	*Eschscholzia californica*	30	47	33	42	25	90	77	70
Clasping Coneflower	*Dracopsis (Rudbeckia) amplexicaulis*	**25**	**0**	**8**	25	**0**	**23**	46	55
Common Sunflower	*Helianthus annuus*	**20**	**25**	42	67	93	87	97	100
Cornflower	*Centaurea cyanus*	51	75	77	80	**3**	**3**	13	35
Crimson Clover	*Trifolium incarnatum*	**13**	**4**	**17**	33	**0**	**13**	42	90
Daylily "Just Mary"[a]	*Hemerocallis* spp.	-	-	-	-	**15**	**20**	13	50
Dwarf Red Plains Coreopsis	*Coreopsis tinctoria*	**20**	**8**	33	60	**10**	**20**	36	50
Field Poppy/Shirley Poppy	*Papaver rhoeas*	**3**	**23**	51	58	**15**	**17**	40	67
Five-Spot Nemophila	*Nemophila maculata*	100	100	100	100	45	65	25	87
Garden Catchfly	*Silene armeria*	100	100	100	100	**0**	33	66	75
Garden Cosmos	*Cosmos bipinnatus*	**8**	**0**	**8**	12	**3**	**3**	**7**	21
Gold Yarrow	*Achillea filipendulina*	100	93	83	100	**10**	**15**	**17**	49
Horned Violet	*Viola cornuta*	**0**	**0**	**0**	**0**	**20**	**20**	**27**	95
Illinois Bundleflower	*Desmanthus illinoensis*	**12**	**0**	**0**	**8**	**0**	**0**	**0**	**0**
Indian Blanket Flower	*Gaillardia pulchella*	67	67	67	67	**15**	**17**	**19**	55
Korean Lespedeza	*Lespedeza stipulacea*	80	85	90	90	**0**	**0**	**0**	30
Lance-leaved Coreopsis	*Coreopsis lanceolata*	**0**	**8**	**0**	**12**	**0**	**0**	**0**	**0**
Lemon Mint	*Monarda citriodora*	100	100	100	100	**16**	100	100	100

Table 5. (Continued)

Common Name	Latin Name	PLATEAU (lbs ae/acre) Pre-emergence 0.063	0.094	0.125	0.25	Post-emergence 0.063	0.094	0.125	0.188
Lupine	*Lupinus perennis*	33	17	5	33	35	51	58	67
Ox-eye Daisy	*Chrysanthemum leucanthemum*	8	0	6	8	0	0	2	11
Plains Coreopsis	*Coreopsis tinctoria*	8	0	26	59	7	5	15	33
Prarie Coneflower	*Ratibida columnifera*	67	83	100	100	12	31	37	62
Purple Coneflower	*Echinacea purpurea*	0	0	6	35	0	0	7	0
Purple Prairie Clover	*Dalea (Petalostemon) purpurea (purpureum)*	100	100	100	100	20	22	22	20
Red Corn Poppy	*Papaver* spp.	20	7	0	0	3	3	11	56
Serecia Lespedeza	*Lespedeza cuneata*	80	90	90	95	0	20	0	40
Shasta Daisy	*Chrysanthemum maximum*	5	16	33	37	0	0	3	23
Showy Partridge Pea	*Cassia chamaecrista*	12	0	0	8	0	0	0	0
Sweet Alyssym	*Lobularia maritima*	100	100	100	100	67	67	67	67
Wallflower	*Erysimum hieraciifolium*	100	100	100	100	50	67	67	67
White Clover	*Trifolium repens*	80	100	100	100	0	0	0	20
Yellow Cosmos	*Cosmos sulphureus*	6	0	7	0	0	7	10	15

[a] (Transplant)

RESULTS AND DISCUSSION

Native Warm Season Grass Tolerance

Results are shown in Table 3. With the excep-tion of eastern gammagrass (*Tripsacum dactyloides*), some emergence of the native warm season grass had occurred prior to chemical application. Little bluestem, big bluestem and Indian grass showed tolerance to all herbicide rates tested. Stand frequency, grass height, and seedling vigor was significantly greater in the treated plots compared to the non-treated area for these three grasses. At 5 months after treatment, big bluestem and Indian grass had flowered in the treated plots while only reaching 6-leaf stage and a height of 20 cm in the non-treated plot. Blue grama (*Bouteloua gracilis*) showed a positive response to PLATEAU treatments up to 0.125 lbs ae/acre, increasing stand frequency.

Sideoats grama (*Bouteloua curtipendula*) treated with PLATEAU was the only grass tested that did not show a significant increase in stand frequency or vigor when compared to the non-treated plot. PLATEAU at 0.188 lbs ae/acre did reduce sideoats and blue grama stand frequency when applied to emerging seedlings. Stand frequency of eastern gammagrass was increased in all PLATEAU plots relative to the non-treated plot. However, at rates of 0.125 lbs ae/acre and higher, a reduction in height occurred. This height reduction was significant for 0.157 and 0.188 lbs ae/acre rates resulting in a 2- and 4-fold reduction respectively, compared to the non-treated check.

Weed Control

For this early post-emergence application timing, there was no difference in weed control between surfactants (Table 4). PLATEAU at

0.063 lbs ae/acre applied early post-emergence, provided good control of barnyard grass (*Echinochloa crusgalli*), giant foxtail, seedling Johnson-grass (*Sorghum halepense*), lamb's quarters (*Chenopodium album*), velvet-leaf (*Abutilon theophrasti*), velvet-leaf (*Abutilon theophrasti*), and jimson weed (*Datura stramonium*). However, this rate was inadequate for other species. At 0.125 lbs ae/acre, PLATEAU resulted in nearly complete control of all weeds tested, including goosegrass (*Eleusine indica*), yellow foxtail (*Setaria glauca*) and common ragweed (*Ambrosia artemisiifolia*).

Some biennial wormwood (*Artemisia biennis*) escaped this treatment, but was severely stunted, reaching only 1/6th the height of wormwood in the non-treated zone. The escaped wormwood was in the mid-rosette stage at application. Small seedlings or wormwood not yet emerged were controlled. Increasing the rate of PLATEAU to 0.157 lbs ae/acre did not significantly increase efficacy on the species tested.

Wildflower Tolerance

Table 5 shows these results. Because the species and treatments were not all within 1 trial, no statistical tests of significance were done on these data. Of the forbs tested, black-eyed susan (*Rudbeckia hirta*), Illinois bundleflower (*Desmanthus illinoensis*), lance-leaved coreopsis (*Coreopsis lanceolata*), showy partridge pea (*Cassia chamaecrista*), horned violet (*Viola cornuta*) and purple coneflower (*Echinacea purpurea*) were tolerant to all PLATEAU rates, pre- and post-emergence.

There were 8 species plus the majority of legumes that showed greater tolerance when the herbicide was applied post-emergence: alfalfa (*Medicago sativa*), blanket flower (*Gaillardia aristata*), Indian blanket flower (*G. pulchella*), white clover (*Trifolium repens*), serecia lespedeza (*Lespedeza cuneata*), Korean lespedeza (*L. stipulacea*), purple prairie clover (*Dalea* [*Petalostemon*] *purpurea* [*purpureum*]), and gold yarrow (*Achillea filipendulina*).

Perennial lupine (*Lupinus perennis*), annual phlox (*Phlox drummondii*), and common sunflower (*Helianthus annuus*) showed tolerance to preemergence treatments, but post-emergence treatments caused desiccation of the growing point.

Species tolerant to PLATEAU at low rates, either pre- or post-emergence were crimson clover (*Trifolium incarnatum*), clasping coneflower (*Dracopsis* [*Rudbeckia*] *amplexicaulis*), plains coreopsis and dwarf red plains coreopsis (*Coreopsis tinctoria*), garden cosmos (*Cosmos bipinnatus*), yellow cosmos (*C. sulphureus*), ox-eye daisy (*Chrysanthemum leucanthemum*), Shasta daisy (*C. maximum*), red corn poppy (*Papaver* spp.) and field poppy/Shirley poppy (*P. rhoeas*).

Baby-blue-eyes (*Nemophilia menziesii*), bird's-eye (*Gilia tricolor*), bishops-weed (*Ammi majus*), garden catchfly (*Silene armeria*), blue flax (*Linum perenne*), and lemon mint (*Monarda citriodora*) were tolerant to only 0.063 lbs ae/acre of PLATEAU post applied and would not be recommended as a primary forb but could be included in a mix for species diversity.

There were 6 species tested that showed no acceptable tolerance to PLATEAU: baby's breath (*Gypsophilia muralis*), baby snapdragon (*Linaria maroccana*), evening primrose (*Oenothera erythrosepala*), flowering flax (*Linum grandiflorum*), globe candytuft (*Iberis umbellata*), and rocket larkspur (*Delphinium ajacis* [*Consolida ambigua*]).

CONCLUSION

Of the rates and application timings tested, 0.094 to 0.125 lbs ae/acre of PLATEAU herbicide applied early post-emergence gave the greatest benefits for prairie establishment in southern Ohio. These treatments resulted in the greatest number of tolerant forb and grass species, while providing adequate weed control. This program would allow a manager to choose from 7 native warm season grasses and 26 different forbs, including all the legume species tested. Research in other states with lower rainfall and less percentage of organic matter in the soil have had greater success with lower rates of PLATEAU, such as 0.063 lbs ae/acre.

SOAR: SUMMER ORIENTATION ABOUT RIVERS

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Abstract: Summer Orientation About Rivers (SOAR) was launched in Hamilton County, Nebraska in 1992 by a group of teachers and the Prairie Plains Resource Institute. It is a nature day camp for elementary school children (grades 3-6) with the aim of getting them out on the land - and in the water-to experience the rich diversity of life just beyond their own back yards. Students enrolled in the one-week camp explore and learn in the field in the mornings, returning to school for afternoon labs. The program takes advantage of the diversity of environments in and around Hamilton County, including the Platte River, the Rainwater Basin, Platte River loess bluffs and other prairie types. The curriculum is interdisciplinary, including activities in natural and physical sciences, agriculture, history, language arts, and art. SOAR has been very successful and has now expanded to a second location in Buffalo County.

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Key words: Buffalo County, Hamilton County, nature camp, Platte River, Prairie Plains Resource Institute, PPRI, Rainwater Basin.

Summer Orientation About Rivers (SOAR) is a nature discovery day camp sponsored by Prairie Plains Resource Institute (PPRI), an educational land trust based in Aurora, Nebraska. The program's purpose is to get local children out on the land and in the water (Fig. 1) to discover the great diversity of life that exists just beyond their own back yards. By using local field sites and an interdisciplinary curriculum including natural and physical science, history, art, agriculture, language arts, and music, SOAR aims to create a deeper appreciation for where we live in the minds of our children.

Hamilton Area SOAR began in 1992, the result of a year's brainstorming amongst several Aurora teachers and the director of PPRI. Its early years received substantial support from the U. S. Fish & Wildlife Service's Biodiversity Project and the Environmental Protection Agency Region VII. The program, which headquarters at the Aurora Middle School in July, has since gained a broad base of support from the community's organizations, businesses, and individuals, and the Upper Big Blue Natural Resources District. The fee for the program is $75 per student for the 5 days which run 8:00-3:30 (except Fridays, which dismiss at 12:30).

SOAR runs for two weeks, one for children who have just completed grades 3-4, and 1 for grades 5-6

Fig. 1. SOAR students in the river.

Fig. 2. Exploring for insects on the Marie Ratzlaff Prairie Preserve.

In Hamilton County, up to 60 students are enrolled for each week, and 12 older students per week, from grades 7-12, take part as "peer leaders." The peer leaders are each assigned a group of 4-5 younger students to guide and assist throughout the week.

Mornings are spent in the field exploring natural areas such as the Bader Park Natural Area along the Platte River near Chapman, or the Marie Ratzlaff Prairie Preserve near the Big Blue River (Fig. 2 and Fig. 3). Usually three or four rotating sessions are held each morning; several of these during the week include guest presenters who are specialists in various disciplines, e.g. ornithology (Fig. 4), ichthyology, herpetology, mammalogy (Fig. 5), entomology, botany, soils, hydrology, art, living history, or storytelling. SOAR returns to the school at noon for lab activities until 3:30. Thursday evenings students return with their families for a program that shows through music, art exhibits, and the "Microbe Show" lab (Fig. 6) everything that has been accomplished during the week.

Fig. 3. "Journaling" at the Marie Ratzlaff Prairie Preserve.

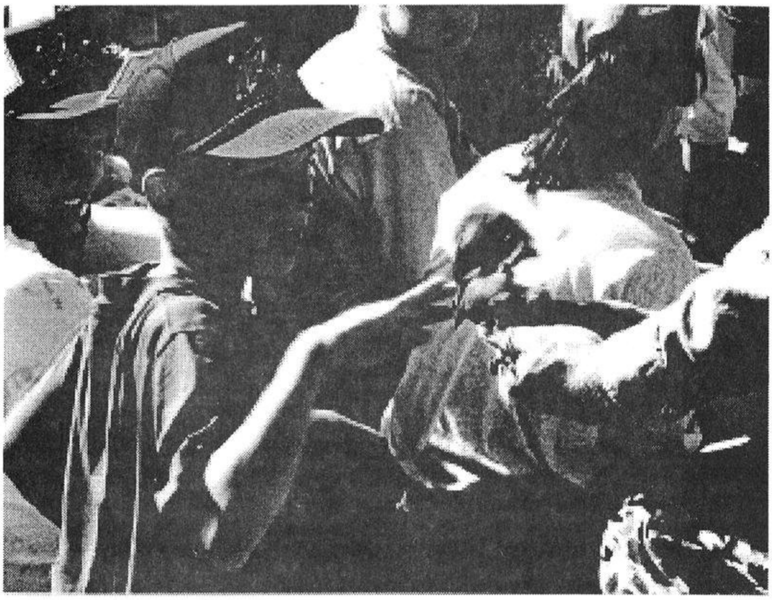

Fig. 4. A close-up of a gray catbird (*Dumetella carolinensis*).

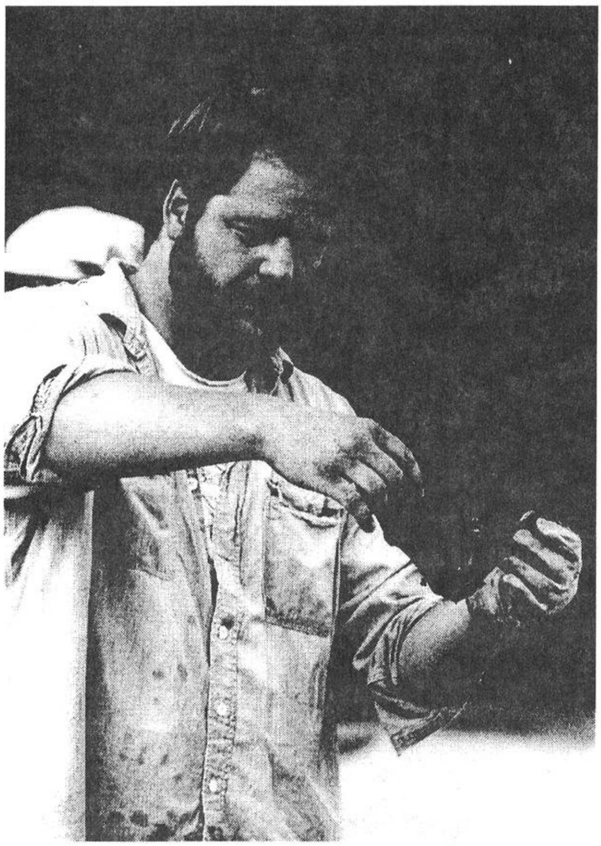

Fig. 5. Russ Benedict, mammal expert from the University of Nebraska, Lincoln, displaying a live big brown bat (*Eptesicus fuscus*).

In 1994, SOAR was listed as one of the five programs which helped Aurora win the Volunteer and Leadership Development category of the Nebraska Community Improvement Program. In 1995, SOAR received an Award of Excellence from the Governor's Council to Keep Nebraska Beautiful. And the USDA Cooperative Extension Service listed SOAR as one of 37 nationwide model programs in a 1995 publication, *Educating Young People About Water: A Guide to Unique Program Strategies*. SOAR was also one of the programs that won the Howard L. Wiegers/ Lincoln Journal Star's Outstanding Wildlife Conservation Award for PPRI in 1998.

In 1995-97, the Central Nebraska Math and Science Coalition provided funding for a SOAR "shadowing" program for area teachers, allowing 8-12 teachers to shadow SOAR each summer and take what they learned back to their own schools. In 1998 the Albion Education Foundation supported three Albion teachers to shadow SOAR.

A second SOAR program, Buffalo Area SOAR, has taken flight in the area of Kearney, Nebraska, based in 1997 and 1998 at Gibbon Public Schools. Outdoor classrooms include the National Audubon Society's Rowe Sanctuary near Gibbon, PPRI's Juhl Prairie near Amherst, and Crane Meadows Nature Center near Alda.

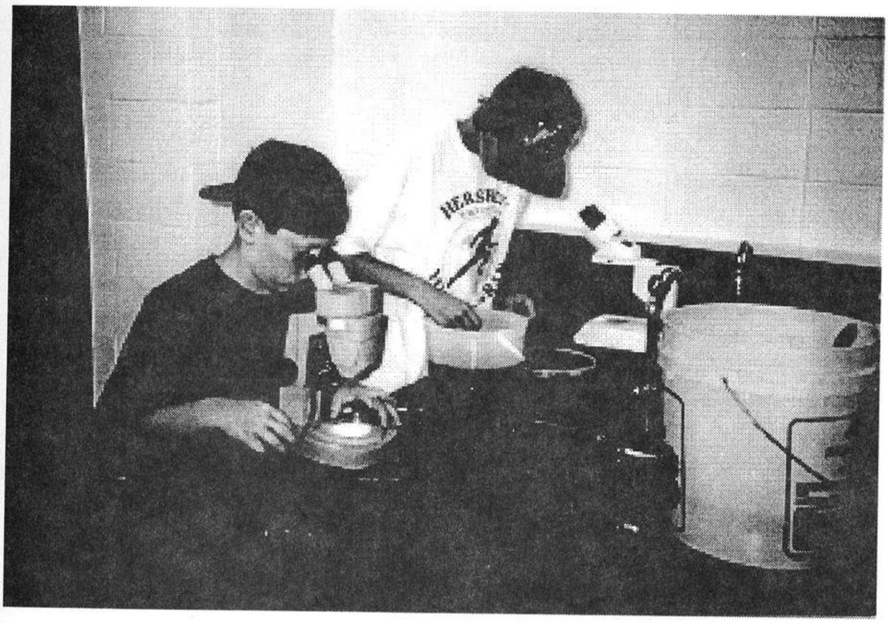

Fig. 6. Looking at the morning field samples for the "Microbe Show."

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