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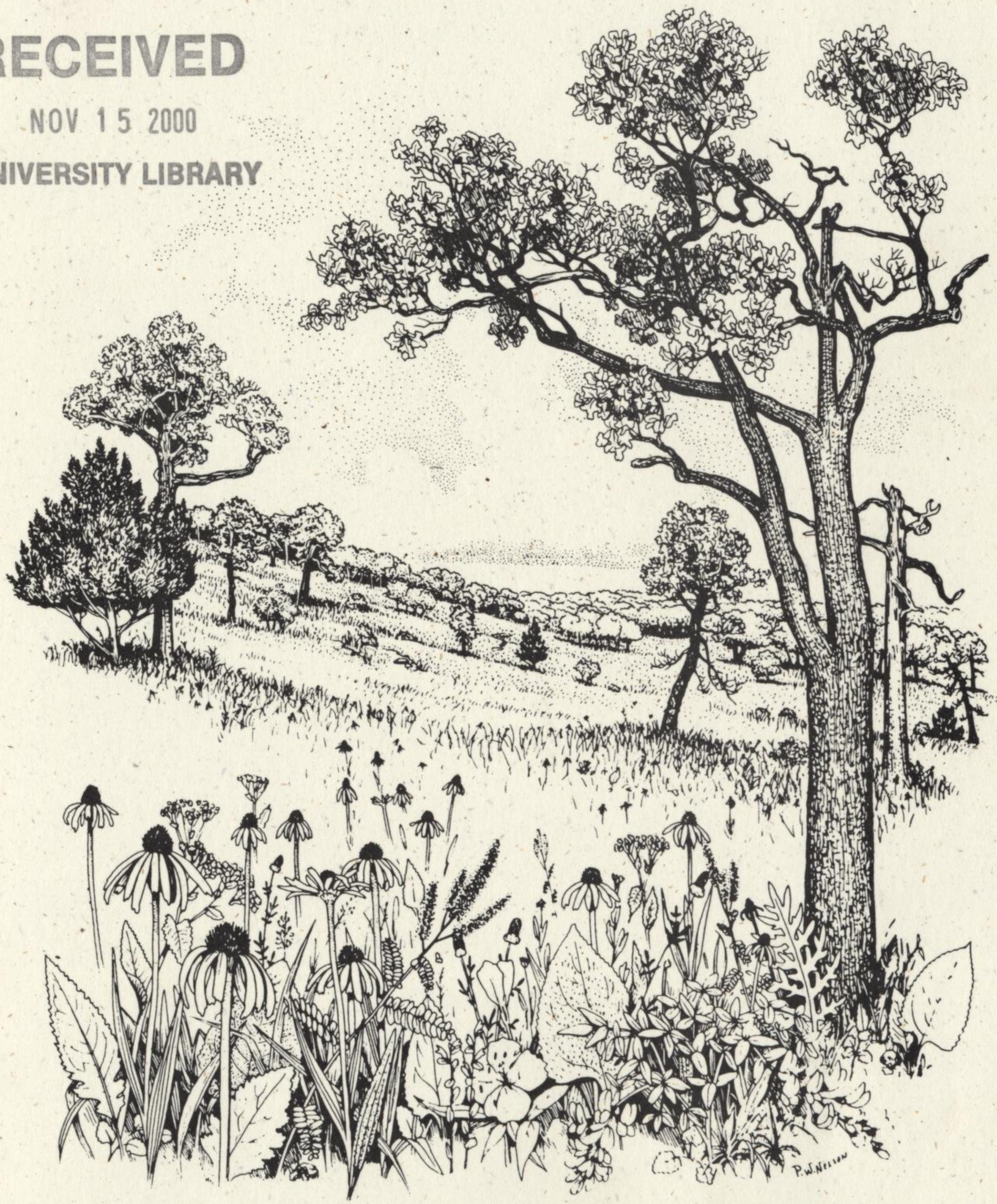
Fifteenth North American Prairie Conference

Proceedings

Charles Warwick, Editor



Fifteenth
North American Prairie Conference

PROCEEDINGS

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THE BIOSPHERE RESERVE PROGRAM IN AUSTRALIA: LANDSCAPE MODELS FOR SUSTAINABLE CONSERVATION AND RESOURCE USE

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ABSTRACT: The international network of biosphere reserves was originally implemented by the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and Biosphere (MAB) biosphere reserve program to protect the world's major biomes or ecological units. Its mission now focuses on the need to reconcile the utilization of natural resources with long-term protection of biodiversity through an interdisciplinary approach to sustaining nature and society. This is the essence of what we now call "ecologically sustainable development." An overview of the functions, concepts, and misconceptions of biosphere reserves is given.

One state-of-the-art model being developed by local communities in the Riverland in South Australia is Bookmark Biosphere Reserve. It draws together community visions, values, and actions dealing with a complex web of environmental and social challenges through a similarly complex network of multiple land tenures, public-private partnerships and resources, and multi-disciplinary professional capacities. Of note is the considerable support this project has been given through the Chicago Zoological Society.

The need to implement and experiment with innovative approaches to sustainability is now more critical than ever. The Biosphere Reserve Program is maturing through better integration of cultural needs and aspirations for quality of life while conserving natural values and ecosystem processes. I wish to encourage more models like the Bookmark experiment to evolve through even greater creativity and engagement with public and private partners.

Key words: UNESCO, Biosphere Reserve, sustainable development, restorative industries.

INTRODUCTION

Ultimately, an adequate conservation strategy depends on a variety of successful policies applied effectively outside reserves to ensure protection of landscape- and seascape-scale ecological functions, habitat restoration, and ecologically sustainable use. Preserved natural areas and other reserves or protected areas are a necessary, but not sufficient condition, for long-term sustainability. Even a comprehensive protected areas system is not a panacea for sustaining ecological diversity—most biodiversity will always be found outside the reserve system. Therefore, networks of protected areas must also be managed in concert with entire regions (Noss 1983; HoRSCERA 1992, 1993; Brunckhorst and Bridgewater 1994, 1995). Protected areas should also function as reference sites—essentially, measuring sticks for landscape wide conservation and sustainability objectives. They are, or should be, of value to local people who share responsibility for conservation across the landscape, both within and outside protected areas (Saunders 1990, IUCN 1993).

As society struggles to come to grips with increasing degradation of the land, its resources, and faltering ecosystems, all governments are realizing their limited resources and professional capacities, to assist social change towards a sustainable future. The Landcare movement in Australia has also contributed to public debate of the appropriate responses of government. Increasingly, authorities from a variety of disciplines (economics, social sciences, biological sciences etc) are also recognizing the limited capacities of traditional forms of public sector organization to deal effectively with the scale, complexity, and inter-relatedness of environmental problems for long-term sustainability. This recognition challenges the ability of compartmentalized government bureaucracies to adjust to, or engage in more integrated on-ground models.

Australia's strategy for Ecologically Sustainable Development (ESD) (agreed upon by all governments in 1992) recognizes that partnerships between government and communities at all levels are vital in the quest for integrated sustainable development and conservation. The Australian Nature Conservation Agency is attempting to meet this challenge through a landscape view of the world which moves its functional units beyond a traditional narrow focus for program delivery. Institutional evolution towards a culture that can encourage and partake of integrated models requires a new definition of management—replacing the idea of control by a few people with that of negotiation and organizational learning. Hence,

PREFACE

It wasn't easy for the pioneers to travel through the prairies of North America, those expansive grasslands fraught with sloughs, potholes, marshes, and a great variety of plant and animal life. Over 100 years later, by contrast, a drive through (former) prairies may invoke boredom rather than wonder and appreciation. Some may realize that this flat, seemingly endless landscape, a product of the action of massive glaciers, was once a vast grasslands that extended through much of the length and breadth of the middle of North America.

Beginning in 1805, land surveyors began the arduous task of dividing the land into townships, preparing the way for the great influx of pioneers that would follow them. These surveyors found that the wildflowers within these grasslands provided a continuous display of color from spring to fall.

Many pioneers shunned the prairies, believing that they surely must be infertile because no trees grew on them. Biting, green-headed flies were the scourge of the prairies during the day in the summer months, and prairies fires, the so-called "messengers of death," raged during the fall. The tough prairie sod made plowing or "breaking prairie" a very formidable task accomplished only with great difficulty until the invention of the self-scouring steel plow in 1837. After this date, cultivation of the prairie proceeded rapidly. Shortly after the Civil War, nearly all of the prairie was gone, except for some dry, sandy prairie, known by some as the "desert land," along the major river systems.

There were a few individuals who lamented the passing of the prairies, but most people were probably glad to see the fires and biting flies fade into history. The few remnants of prairie that remained were located on dry, sandy soils, in pioneer cemeteries, or on high, nearly inaccessible bluffs along major rivers. Today, these remnants are now threatened by encroaching native woody vegetation, exotic plant species, and both agricultural and urban development.

Much has been learned from several decades of prairie reconstruction and research. The application of this knowledge at sites throughout the U.S., such as the Midewin National Tallgrass Prairie (a 15,300-acre site) and the Savanna Army Depot with 4,500 acres of prairie and savanna in Illinois, will help ensure the presence of extensive prairies in the future. Much will be learned from the restoration and reconstruction of these and other sites throughout North America, and people will once again see prairie grasses and wildflowers stretching from horizon to horizon.

These proceedings of the Fifteenth North American Prairie Conference in St. Charles, Illinois, contain papers on fire ecology, succession, seedling establishment, data from nearly two decades of prairie reconstruction, and many other prairie-related topics. This information, together with papers on remnant prairies, will provide valuable guidance for the management and preservation of our diverse grasslands. A special thanks is given to all contributors, participants, and organizers that made this conference possible.

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WHAT PEOPLE THINK ABOUT ECOLOGICAL RESTORATION AND RELATED TOPICS: A FIRST LOOK

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ABSTRACT: This study represents a first step in gaining awareness of what people think about ecological restoration and related concepts. Forty-one undergraduate nonscience majors at a liberal arts college in Chicago were asked to define, explain, or illustrate the following four terms: "forest preserves," "natural area," "ecological restoration," and "biodiversity." Analysis involved repeated readings of responses and identification of common themes. Forest preserves held a variety of meanings for people while natural areas often were equated with nature in its most pristine form. The term ecological restoration often translated to fixing the mistakes of man, usually by planting trees. Biodiversity was an unfamiliar term for most respondents. Overall, trees appeared to be an important icon for forest preserves, natural areas, and ecological restoration. This is important information especially when restoration efforts involve removal of trees. Rarely did respondents associate ecological restoration with replacement of one type of community (e.g., forest) with another (e.g., savanna). Learning how people perceive restoration and related concepts may be a good first step in involving a larger population in restoration efforts.

Key words: forest preserve, natural area, ecological restoration, biodiversity

INTRODUCTION

Ecological restoration is increasingly being used as a tool for enhancing the biodiversity of areas and re-establishing healthy ecosystem functioning. As Stevens (1995) describes, "More and more conservation biologists are coming to recognize restoration as an essential weapon in the struggle to head off the possibility of mass extinctions and collapses of ecosystems."

Somewhat surprisingly, the Chicago area (including Cook and the surrounding counties) is home to some of the largest and best surviving remnants of rare oak and prairie ecosystems (Friederici 1997). It may seem incongruous that the Chicago Metropolitan area, home to 8 million people, is also the site of some of the most unique habitat in the world. This biological wealth is a function of early, farsighted planners who preserved open space in and around the city. The forest preserve districts of Cook and surrounding counties thus have potential for restorationists interested in rescuing and restoring rare biological diversity: Realization of this potential is confounded by the fact that these areas are located in the "backyard" of millions of people, and these people may have specific images of what the forest preserves represent—images that may have been formed over decades.

A better understanding of what is occurring in forest preserve restoration in the Chicago area may be gained by looking at the history of the preserves According to Joseph Nevius, General Superintendent of the Forest Preserve District of Cook County, the forest preserve district has undergone three distinct eras in its 80-year history (Stewart 1995). In the earliest era, from the 1920s–1950s, the district focused on land acquisition Much of the acreage obtained by the district in those early years was abandoned farm fields. Reforestation of these lands with native hardwood trees and shrubs was a major activity in the 1930s and 1940s (Wendling et al. 1981). From the 1950s through the 1980s much attention and effort were directed toward the recreational development of some of these areas through construction of facilities such as bike trails, picnic areas, and golf courses. Wendling et al. (1981) describe the preserves as "forested sanctuaries—large natural reservations with recreation facilities for intensive use on their fringes."

Restoration of both constructed and natural features has been the emphasis of the most recent era beginning in the early 1990s (Stewart 1995). Although restoration has been occurring throughout forest preserve history, the formation of a multi-agency partnership has spurred restoration efforts within the last few years. Ecologists contend that over the years, since the forest preserves were established (in the early 1900s), they have undergone degradation partly due to the absence of effective stewardship (Forest Preserve District of Cook County 1996). As the forest preserve district has been developed during the past 80 years, fire has been excluded from its ecosystems, some of which depend on it for their health,. Also, weedy species have become dominant in some cases. In support of a more ecological approach to management, the Forest Preserve District of Cook County currently is engaged in cooperative planning efforts to restore native ecosystems and apply the principles of ecosystem management in the district's holdings (USDA Forest Service 1995).

As these plans for ecological restoration in the forest preserves begin to be implemented, restoration activities will become more visible and salient to the public. Restoration by definition involves change, and often these changes occur at an accelerated pace bringing them to the attention of neighbors, visitors, and passersby. Many of them may wonder what is happening and why. The layperson often has not had the types of experiences that foster knowledge and appreciation of rich and biologically diverse systems (Chipeniuk 1995).

An article in the Chicago Tribune (Martinez 1995) illustrates some of the challenges facing restorationists in urban areas. The article describes a plan by the local park district to convert a 20-acre lot that had stood vacant since the late 1970s into a nature sanctuary with renewed savannas, wetlands, and prairies. Local residents claimed the area "is already a nature sanctuary" and that "the plan is redundant." It is a small stretch to imagine similar scenarios of public resistance playing out in the course of restoration efforts in the forest preserves.

In contemplating the increased restoration activities on forest preserves in this region, we began to wonder how forest preserves were perceived by area citizens who are not personally or professionally involved with restoration. We also wondered how people perceived natural areas and whether these perceptions were different from those associated with forest preserves. We also wanted to find out what people thought ecological restoration was all about? Finally, we wanted to determine what the term "biodiversity" meant to people?

METHODS

Participants

Forty-one undergraduate students at Columbia College participated in the study. The students were members of two Ecology and Human Affairs classes and were all nonscience majors. Columbia College is a private, four-year Art, Design, and Communications college. It is located in downtown Chicago. The students participating in the study ranged in age from 18–29 with a mean age of 21 years. Over two-thirds (68%) of respondents were male. The majority of class members were white (76%), however African Americans (12%), Hispanics (10%) and Asians (2%) also were represented. Nearly two-thirds (64%) of the students resided in the city of Chicago, while 36% lived in the suburbs.

Materials and Procedure

Surveys were administered during the first day of classes in the spring semester, February 1996. Prior to distributing the surveys, the instructor introduced herself and briefly explained the study objectives.

Each student was then handed a sheet of paper with the following printed at the top, "What words come to mind when the term Forest Preserves is mentioned?" Students were given 5 to 10 minutes to complete their responses. These sheets were collected and a similar procedure was followed for three other questions. On a second sheet respondents were asked to draw or describe a natural area, possibly a place they had visited and were familiar with, or some place they had heard about, seen in pictures, magazines, or movies, or a purely fictional place that appealed to them. On a third page students were instructed to diagram or describe ecological restoration, what they thought the term meant, and where they most likely would find this happening? Finally, respondents were asked, to define the term "biodiversity," where it exists in the Chicago and Cook County areas, and to draw and/or describe the phenomena of biodiversity. Background information on study participants was gathered from index cards completed by each student.

Analysis

The goal of analysis was to capture and summarize the main ideas participants expressed about the four concepts (forest preserves, natural areas, ecological restoration, and biodiversity). To conduct analyses, responses to each of the questions were grouped and read repeatedly. Through this process common themes or recurring ideas related to each of the four concepts emerged. Once a set of themes was identified, responses were coded into theme categories. Some responses could be broken down into more than one thought, thus, it was possible that an answer given by a single respondent could be coded into more than one theme category. Going back and categorizing responses into theme categories served as a cross check to assure that the complete set of ideas generated by respondents was represented. The approach used in analysis of this material was modeled after Schroeder (1996) for interpreting textual material.

RESULTS

Over three-fourths of those who participated in this examination said they had previously visited a forest preserve. A greater proportion (87%) said they had visited a natural area. Most participants expressed themselves in words. In seven instances, a drawing formed the predominant portion of the response.

In the following four subsections, results of analysis of written responses on each of the four concepts are reported. Commonly occurring themes are shown in **bold** type. Each theme is illustrated using quotes from respondents. The order of the paragraphs reflects the prevalence of the theme in the responses, i.e., the first theme discussed was most prevalent, the second theme was second most prevalent, etc.

Forest Preserves

Much of the restoration planned for the Chicago area will occur on land currently designated as county forest preserves. Thus, we felt it was important to ask about the meanings forest preserves held for people. Thirty-seven subjects responded to the question about forest preserves. Perhaps not surprisingly, **trees**, **forest**, or **wooded** were words that came to mind, with some suggesting that there were lots of trees or the woods were dense. "When I think of the term 'Forest Preserves' I envision a densely wooded area that has little effect from mankind. I picture a forest full of trees..."

The fact that these areas were **protected** from development, or set aside, seemed to be a defining feature. "It is a protected woodsy area that allows people to enjoy the natural setting. Land that men or women can't mess with as far as buying. Put aside for the enjoyment of people and animals."

Forest preserves were described with the words **nature** and **natural**, although there was an interesting discrepancy about how natural forest preserves actually were. From one perspective, a forest preserve is "a completely natural area full of plants and animals..." Another view was that a forest preserve represents, "Nature contained." Alternatively, a forest preserve was described as: "a forest which has been preserved in its natural state, but not all of it since some forest preserves have parking lots and driveways and outhouses and grills..."

People believed it would not be unusual to find some **wildlife** like birds, deer, fish, reptiles, and rodents in forest preserves. It was suggested that forest preserves are "...meant to keep certain types of wildlife thriving that wouldn't be able to survive just a few miles down the road."

Respondents believed forest preserves were places to **do** a variety of things. Forest preserves were described as being "...maintained for the purpose of walking, enjoying nature, playing with children", or as "somewhat like parks that people just sit for privacy and sometimes enjoyment." Others mentioned "partying with friends," "picnics during the summer," and "hiking with the dog and mountain biking" as activities they would pursue at forest preserves.

Respondents expected to find **built or maintained structures** such as "pathways through the trees for biking, walking, skating," "occasionally a picnic area," or "...benches and a lot of space to do whatever it is you do." Bodies of **water** were mentioned in descriptions of forest preserves:"... there are about a couple of lakes—usually manmade."

Forest preserves were described as clean with the implication that this would make them somewhat of an oasis in the city. Respondents said forest preserves were, "Clean, untouched, preserved, fun, an escape from busy and dirty streets. Free of trash, filth, and people. A peaceful area where much of life is living at its fullest away from the city, fast life, and pollution."

Natural Area

The restoration process at a site is often undertaken to make the site more natural. We wanted to see how participants viewed natural areas. Thirty-six subjects responded to the question about natural areas. **Plants, trees,** and **greenery** in general were commonly mentioned in descriptions of natural areas. According to respondents, natural areas contain "Bluegreen grass, tall trees, mountains with a river running through a valley... Only the plants and animals are there. A natural area should have abundant greenery."

Natural areas were often described as places that are **untouched**—"a natural area is a place that hasn't been touched by industry; ...a place untouched by the hands of man; man has not made these particular places with technology or knowledge; these places are of nature's creation."

The presence of water in some form appears to be important in defining a natural area. Picture a place where, "the high mountain glades are cut with streams," or "a waterfall in a tropical rain forest in Brazil." To some, a natural area is a place that fills all the **senses**. "I imagine a place that is fragrant... All around are gorgeous trees blooming with flowers. It's quiet and peaceful. A natural area to me is a beach, watching, and listening to the waves. Feeling the sun on my face."

Animals also seemed to be symbolic of natural areas. "A natural area ...is an area which harbors several types of flora and fauna which continue their cycle of death and reproduction without human intervention. Animals and plant life in balance and undisturbed."

Quite a variety of specific **places** were mentioned as representations of natural areas. "I imagine the rain forests of Brazil. A natural area that I have visited and think of frequently is the Rocky Mountain National Park. An example of a natural area that I have been to is the North Woods in Wisconsin. The most natural area I've been to is a small valley at the other end of Mexico. The only natural area I can think of is my aunt's house in Madison, Wisconsin, because she lives on a farm..."

Ecological Restoration

Thirty-six subjects responded to questions about ecological restoration. Ecological restoration often conjured up images of **fixing** or **repairing** areas that had been harmed by humans. "This would involve repairing an area that was previously damaged by people. Bringing life back into a dead zone where man has destroyed all life for his greed for money. Fixing our mistakes."

The idea of making things more **natural** was associated with ecological restoration. Ecological restoration was described as "restoring of the basic or natural make-up of the ecosystem; an effort to restore the balance God had intended; or Mother earth if you will. Resorting back to a more 'natural' life style and natural system."

Cleaning, and making **healthier** were words used in describing ecological restoration. "Ecological restoration is when an area has been damaged environmentally, and there is an effort to make it healthier." It connotes, "...cleaning dirty water, picking up trash all over, in the forest or in the city, by factories and beaches. It could also mean Mother nature 'restoring' earth or cleaning itself because of human's reckless abandon."

Planting or **replanting trees** was another theme identified. Respondents suggested ecological restoration means "replanting trees where clearcutting has taken place," or "planting trees, cleaning dirty rivers and oceans in order to bring nature back to the planet. The actions involved in ecological restoration can run the gamut from planting trees to saving mating pairs of endangered animals to boycotting nonanimal-friendly products."

There was some degree of **uncertainty** expressed on what ecological restoration means. Some were sure they didn't know what it meant. "I have exactly no idea." Others were uncertain but willing to venture a guess. "By the sounds of the words I get the picture of restructuring. "Perhaps restoring/rebuilding something...."

Biodiversity

Ecological restoration may be undertaken for the purpose of increasing biological diversity in an area, so we were interested in what this term meant to participants. Thirty-one subjects responded to the question about biodiversity. There was a lot of **uncertainty** about what the term biodiversity means. "I haven't the slightest idea what this word means" and "no clue" were not unusual responses. Some ventured guesses. "Diversity in twos? ...To take a guess I would say some sort of bringing something together, or taking two groups of different things and binding them."

The word did seem to connote **many** or **varied** species to some. Biodiversity was associated with "existence of various living things, many types of animals and plants, and biological differentiation." **Co-existence** was also mentioned. Biodiversity suggested "coexisting without dangerous harm to one another; an area where many, or more than one organism coexist together, and directly have an effect on each other; and all things coming and living together."

The presence of **humans** and/or **culture** were included in definitions of biodiversity. "Biological diversity means there are many different or diverse people, plants, animals; from races to religions its all over, everywhere you look. It could be the many different cultures that could be found within the city, and it could be many different species living together in one world."

DISCUSSION

In the Chicago metropolitan area, forest preserves are one environment where ecological restoration is being planned. From this study we have learned that forest preserves are viewed quite broadly and heterogeneously. Trees were a unifying concept that most people associated with these areas. This finding is consistent with results of an earlier study of forest preserves (Young and Flowers 1982) that found trees to be the most frequently mentioned feature contributing to site attractiveness. That forest preserves were areas protected from development was also commonly mentioned in our study.

There were discrepancies in how respondents perceived the level of naturalness inherent in forest preserves. Some viewed them as very natural while others noted many built features. There was also variation in the type of experience people sought from forest preserves, with some people associating them with active pursuits such as biking and skating, while others sought peace and quiet. A number of respondents suggested forest preserves would provide homes for wildlife. The most commonly mentioned wildlife species tended to be ones that the professional biologist or restorationist might consider pests (e.g. deer, squirrels, raccoons, and rabbits).

In contrast to forest preserves, natural areas tended to be more clearly and singularly equated with nature in its most pristine, untouched, and pure form. Natural areas were described in an almost Disney-esque way. They were described as places with snowcapped mountains, magnificent waterfalls, gorgeous trees, bluegreen grass, where brooks bubble and animals roam. Most of the specific places named in the course of talking about natural areas were not close by, but three people did give local examples. One thought of Lake Michigan as a "place that has naturally grown to be whatever it is." Another mentioned cutting brush in a natural prairie in Lake Forest, Illinois. One person contrasted forest preserves and natural areas with the following statement, "When I think 'natural area' I picture the woods (forest preserves). I know it is not technically natural, but to me, natural means pure and peaceful and that's how I view the forest preserves."

Ecological restoration often translated to cleaning up or fixing mistakes, such as strip mining, clearcutting, or oil spills. There was a lot of emotion and judgment in these responses. According to respondents, ecological restoration would be needed where man has "abused, butchered, and destroyed". That forest preserves would be the site of ecological restoration efforts may be a difficult one for people to fathom given the meaning the term ecological restoration had for participants. Participants suggested that some goals of restoration would be to make things more natural, cleaner, and healthier. Planting and replanting trees were mentioned as means to achieve these goals. Trees were found to be an important icon for forest preserves and natural areas as well. This may make restoration efforts that involve the removal of trees particularly confusing to people. The idea that one would restore an open space (e.g. a weedy field) to a more natural condition (e.g. a prairie) was not common in participant responses.

The term biodiversity was not very familiar to study participants. The words "many" or "varied" species were mentioned by some who provided responses. Only a few respondents alluded to ecosystem functions or processes. Co-existence that encompassed not only plants and animals but people and culture was another idea that came up.

Perhaps this last idea is one worth giving further consideration. The human dimension, that is the people who live near, play in, pass by, and/or read about areas being restored, may be as important to today's restoration efforts as are the seed mixes, the planting techniques, and the soil fertility. As one respondent put it, "I think ecological restoration means the repairing of not only our environment, but the relationship we have with the environment and how we can work together to a better end."

CONCLUSIONS

This study was a preliminary exploration of the ideas people have about ecological restoration and the related concepts of forest preserves, natural areas, and biodiversity. The small sample size and the non-random nature of the sample do not allow us to estimate the proportion of the population that holds specific views. The important consideration of our research goals was that respondents were urban people and did not have special knowledge about ecological restoration.

Our findings suggest that people are able to articulate a range of perspectives about what forest preserves and natural areas mean to them. However, they are quite unfamiliar with the concept of biodiversity. Ecological restoration often translated to disaster mitigation. This narrow interpretation would not encompass many of the activities restorationists typically engage in. Attempts to sell restoration to the public by emphasizing the outcome of enhanced biodiversity may not be effective given the low level of understanding of this concept.

As we increasingly look to urban and suburban areas for remnants of disappearing habitat and rare species, it is important not to ignore the human dimension. According to Perry (1994), restorationists tend to focus on the restoration site and its ecological history, paying less attention to the multidimensional landscape that surrounds a project. This landscape includes the social as well as biological and physical contexts.

Determining what people think about ecological restoration and related concepts is one way to weave the human social dimension into restoration projects. At the same time, we as resource professionals, scientists, and managers need to do a better job of communicating our messages. Among the strategies for facilitating communication about topics such as biodiversity and restoration are the following: clearly define concepts; make the issues real—not conceptual; use local examples when possible; make the human connection and explain how people are not only responsible for ecological degradation but also ecological restoration; and finally, speak in plain English using nontechnical terms (Saunders and Skosey 1998).

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INSECT HERBIVORES OF 12 MILKWEED (*ASCLEPIAS*) SPECIES

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ABSTRACT: To better understand the relationships between insect herbivores and their plant hosts, a study was undertaken involving the insect herbivores closely associated with milkweeds. More than 30,000 plants belonging to 12 milkweed species (*Asclepias amplexicaulis*, *Asclepias exaltata*, *A. hirtella*, *A. incarnata*, *A. lanuginosa*, *A. meadii*, *A. purpurascens*, *A. sullivantii*, *A. syriaca*, *A. tuberosa*, *A. verticillata*, and *A. viridiflora)* were studied, and approximately 750 specimens of 16 species of insect herbivores were observed feeding on these milkweeds. These 16 species were: a) 2 hemipterans (*Lygaeus kalmii*, *Oncopeltus fasciatus*), b) 4 coleopterans (*Tetraopes tetraophthalmus*, *T. femoratus*, *Labidomera clivicollis*, *Rhyssematus lineaticollis*), c) 3 lepidopterans (*Danaus plexippus*, *Cycnia tenera*, *Euchaetias egle*), d) 5 hompterans (*Aphis gossypii*, *A. nerii*, *A. rumicis*, *Myzus persicae*, *Macrosiphum rudbeckiae*) e) one dipteran (*Liriomyza asclepiadis*) and f) one thysanopteran (*Frankliniella tritici*). The food preferences of these herbivores for the different species of milkweeds, the part or parts of the plants that were preferentially used in feeding, and the insects' relative abundance throughout the growing season were determined. Differences between this study and others of a similar nature are discussed. Changes that may have occurred in the host-herbivore relationships with the destruction of the presettlement environment also is discussed.

Key words: milkweeds, insects, herbivores

INTRODUCTION

There have been relatively few surveys on insects associated with milkweeds *(Asclepias spp)*. Weiss and Dickerson (1921) listed 122 species of insects found on two species of milkweeds *A. syriaca* and *A. incarnata pulchra* in New Jersey together with ecological notes on the ecology of seven insect herbivores. Wilbur (1976) provided important additional ecological information on eight herbivorous species found on seven species of milkweeds (*A. exaltata, A. incarnata, A. purpurascens, A. syriaca, A. tuberosa, A. verticillata,* and *A. viridiflora*) in south-central Michigan. Both of the above studies provide qualitative estimates of herbivore abundance on each milkweed species, by using terms, such as, "very frequent," "frequent," "occasionally," and "rare." In another study, Dailey et al. (1978) collected 5959 beetles belonging to 25 families from a population of *A. syriaca* along a railroad right-of-way in Bowling Green, Ohio. They also included data on the relative seasonal abundance of 23 of the more abundant species collected. Price and Willson (1979) using quantitative data, reported on the relative abundance of 12 milkweed herbivores found on 6 species of milkweeds (*A. amplexicaulis, A. incarnata, A. sullivantii, A. syriaca, A. tuberosa,* and *A. verticillata)* in central Illinois. Ecological data on the herbivores was also included in the paper.

Between 1964 and 1967 extensive field studies were undertaken to understand better the relationships among 16 milkweed herbivores and 12 species of their *Asclepias* hosts. These studies were continued sporadically during the next quarter of a century. Data were collected on the herbivores' preferences for the different species of *Asclepias*, the parts of the plants they fed on, and their relative abundances throughout the growing season. Additional data were collected on the kind and extent of damage done to the host plants.

STUDY AREAS AND METHODS

With the exception of *A. meadii,* all of the milkweed species studied occurred in the greater Chicago region. This area included southeastern Wisconsin, northeastern Illinois, and northwestern Indiana. Except for one specimen of that species from east-central Illinois, all of the 180 specimens of *A. meadii* studied were from western Missouri and eastern Kansas. In all there were 145 stations, involving 35,801 stems and 54,560 observations of these stems (Table 1). These *Asclepias* species were found in all types of habitats including: sand (*A. amplexicaulis*); virgin mesic prairie (*A. meadii*); dry prairie (*A. lanuginosa*, *A. tuberosa*, and *A. viridiflora*); wet prairie (*A. hirtella* and *A. sullivantii*); woods (*A.

Table 1. Numbers of *Asclepias* stems observed, numbers of stations where *Asclepias* plants occurred, and number of stem observations for herbivorous insects.

Asclepias Species	Number of Stems	Number of Stations Where Species Occurred	Number of Stems Observed
A. amplexicaulis	318	4	952
A. exaltata	94	6	449
A. hirtella	216	8	639
A. incarnata	1117	17	2839
A. lanuginosa	600	2	1862
A. meadii	180	17	621
A. purpurascens	198	5	461
A. sullivantii	3276	12	4012
A. syriaca	5123	41	7679
A. tuberosa	2438	10	3258
A. verticillata	22092	18	31312
A. viridiflora	149	5	476
Total	35801	145	54560

exaltata); savanna (*A. purpurascens*); marshes (*A. incarnata*); old fields (*A. verticillata*); and waste places and cultivated fields (*A. syriaca*).

In this study the stem was used as the unit of reference rather than an individual plant because of the difficulty in distinguishing between individual plants in many milkweed species. Only in a few milkweed species, such as *A. meadii* and *A. tuberosa*, is it usually easy to make that distinction, because when ramets are produced they generally grow adjacent to one another from a single rootstock forming a clump. However, this is not the case with many of the other milkweeds studied. Species like *A. sullivantii, A. syriaca*, and *A. verticillata* have a tendency to produce extensive rhizomatous systems which produce spreading ramets that intermix with ramets from other clonal systems. This makes it impossible to determine one plant system from another. A mechanical hand counter was very useful in determining the number of stems in most of these clonal species.

However, it was frequently difficult to count the number of stems in *A. verticillata* colonies using such a device because they produce large colonies, covering extensive areas with hundreds of ramets free of any other plant growth. Since *A. verticillata* has narrow linear leaves, it was possible to view and examine the whole colony at once and to determine the presence of any herbivores on them. The approximate number of stems in colonies of this species was then determined by counting the number of stems in a square meter and extrapolating this figure to include the entire area of the colony. It is interesting to note that the number of stems/meter varied from one colony to another (Rommel 1967).

The studies were conducted from early June to early October during daylight hours. Most of the milkweed populations were carefully examined for herbivorous insects approximately every two or three weeks, and the herbivore species and their number on the different milkweed species were then recorded. Except for an occasional uncommon species, none of the other insects specimens was collected. Because specimens were not collected and removed from a station, it is possible that they could have been recorded again in a follow-up observation two or three weeks later. Because of this possibility, the term "observation" was used for recording the presence of a specimen found on a stem.

Periods of Insect Abundance

In the bar graphs showing the periods of insect abundance, the y-axis is labeled "Number of Insects" and the x-axis "Weeks." The "Number of Insects" is an estimated number of insects.

Since the number of milkweed plants observed for an insect species varied from week to week, the number of specimens observed each week could not be used as a true measure of the actual abundance for that insect over the time period used (first week in June to the fourth week in September). Because of this, it was necessary to calculate estimated numbers of insects observed during any given week within that period.

This was done by using the following formula: The estimated number of insects equals the number of insects observed on milkweeds during any given week **times** the total number of milkweeds observed throughout the period of observations **divided by** the number of milkweeds observed each week.

Most blank spaces for weeks in the figures indicate that insect observations were not carried out during those weeks and not because there was a lack of insects.

RESULTS

Bugs (Hemiptera)

Small milkweed bug (*Lygaeus kalmii* (Stahl)
This species belongs to the Lygaeidae or seed bugs. It is brightly marked with red and black, having a red X-shaped area on the hemelytra and a broad red band across the base of the pronotum. Both adults and nymphs feed on the juices of milkweeds during the early part of the growing season. During late fall and early spring they have the ability to survive on the matured seeds and dehisced pods of milkweeds.

This species was found on 10 of the 12 milkweed species studied. It has a preference for *A. incarnata* (14.0 specimens/1000 stems) and to a lesser extent *A. viridiflora* (10.5/1000) (Table 2). Sixty-three percent of the specimens observed on *A. tuberosa* were found on the pods, with another 20% on the leaves (Table 8).

Two generations a year were reported in the literature; the first generation appearing about the last week in June and the second in early August (Simanton and Andre 1936). However, this study indicates that there are three periods of abundance: 1) a relatively short one during the second week in July; 2) a long one during the second week in August and 3) a moderate one during the third week in September (Figure 1).

Usually only one or two specimens are found on a milkweed stem at any one time and cause very little damage to the host plant and its crop of seed.

Large milkweed bug (*Oncopeltus fasciatus* (Dallas)
This species also belongs to the Lygaeidae. Like *Lygaeus kalmii*, adults also are marked brightly red (older) or orange (younger) with three broad horizontal black bands. The nymphs are red with black antennae and legs. The adult bugs are easily sexed, with the male bearing a black band and the female two prominent black spots on the ventral side of the fourth abdominal segment (Lener 1966, Best 1977).

This species was found on 8 of the 12 milkweed species studied, having a preference for A. viridiflora (14.7 specimens/1000 stems), *A. syriaca* (13.4/1000), and *A. incarnata* (8.5/1000) (Table 2). Seventy-five percent of the specimens observed on *A. syriaca* and *A. incarnata* were found on the pods (Table 8).

Specimens of this species appeared during the first week in July with a rapidly increasing population reaching a peak during the fourth week in September (Figure 2). Toward the end of summer, this species usually occurs in clusters of 10 to 15 nymphs along with an adult or two. The number of nymphs is probably related to the number of eggs originally laid by a female on the surface of the pods.

Both the adults and nymphs are usually found on the pods (follicles) where they feed on the developing seeds within

Table 2. Number of *Lygaeus kalmii* and *Oncopeltus fasciatus* adults observed on *Asclepias* species.

Asclepias Spp.	Lygaeus kalmii: No.of Insects Observed on	Lygaeus kalmii: No.of Insects per 1000 Stems	Oncopeltus fasciatus: No.of Insects Observed on	Oncopeltus fasciatus: No.of Insects per 1000 Stems
A. amplexicaulis	1	1.1	2	2.1
A. exaltata	1	2.2	0	---
A. hirtella	5	7.8	1	1.9
A. incarnata	40	14.1	26	9.2
A. lanuginosa	0	---	0	---
A. meadii	0	---	0	---
A. purpurascens	2	4.3	0	---
A. sullivantii	5	1.3	9	2.3
A. syriaca	24	3.1	103	13.4
A. tuberosa	21	6.4	11	3.4
A. verticillata	38	1.2	11	0.4
A. viridiflora	5	10.5	7	14.7
Total	142		170	

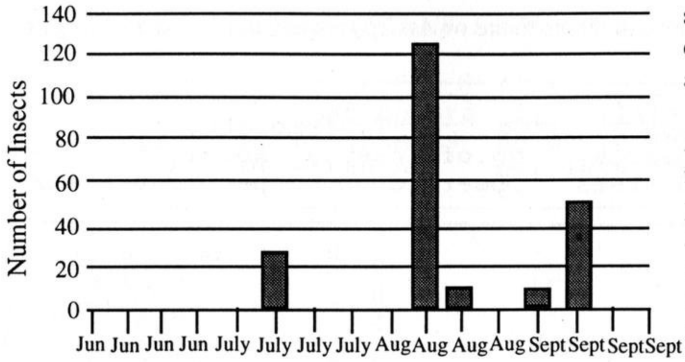

Figure 1. Weekly abundance of *Lygaeus kalmii* on *Asclepias tuberosa*, adjusted as in text.

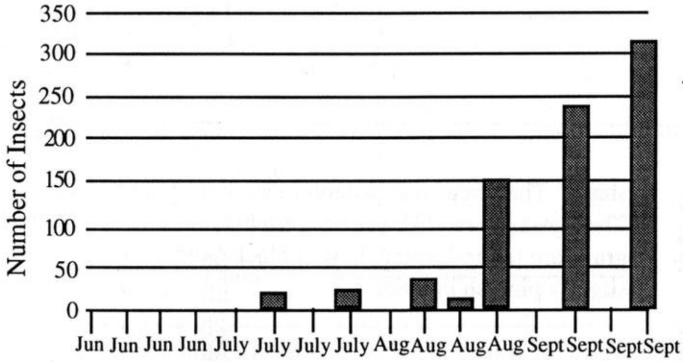

Figure 2. Weekly abundance of *Oncopeltus fasciatus* on *Asclepias incarnata* and *A. syriaca*, adjusted as in text.

the pods. Pods that are infested are peppered with hardened plugs of milky juice, sealing the holes produced by the insertion of the herbivores' beaks. Except for the seeds in a relatively few pods eaten by the clusters of nymphs on them, this herbivore causes little damage to the host stem and its crop of seed.

Beetles (Coleoptera)

Common milkweed beetle (*Tetropes tetrophthalmus* Forster) and **western milkweed beetle** (*T. femoratus* Leconte).
The adults of *T.* te*traophthalmus* are red with four black spots on the pronotum and two pairs of black spots and one pair of vertical bars on outer edge of the elytra. The adults of the similar *T.* fe*moratus* differ from the former species in having gray rings around the antennal segments and lack the vertical black marks on their elytra.

A third species of this genus, *T.* q*uinquemaculatus* Haldeman, is also found in this region, but was not observed in this study. This species can be distinguished from *T. tetraophthalmus* by its lack of anterior elytral spots, its slightly annulated antennae, and the coarse elytral punctures. The nonelevated thoracic umbone will at once separate it from *T. femoratus*. (Chemsak 1963).

Adults of *T.* te*traophthalmus* were found on 8 of the 12 milkweed species, showing a preference for A. purpu*rascens* (19.5 specimens/1000 stems) and *A. syriaca* (19.4/1000) (Table 3). Price and Willson (1979) also observed adults of this species on *A. incarnata*. More than 80% of the specimens were found on the leaves (Table 8). Specimens were first observed during the second week in June and increased to a peak during the first week in July with the last specimens found during the third week in August (Figure 3).

T. femoratus was a much more rarely observed beetle in this study compared to *T. tetraophthalamus*. Thus, 18 observations of *T. femoratus* were made compared to 175 observations of *T. tetraophthalmus*. The adults of *T. femoratus* were found on 8 of the 12 milkweed species studied, showing a preference for a number of milkweed species, especially those that are rather uncommon. These include *A. lanuginosa* (1.1 specimens/1000 stems), *A. meadii* (1.6/1000), *A. hirtella* (1.9/1000), and *A. viridiflora* (2.1/1000) (Table 3). More than 94% of the specimens observed were found on the leaves (Table 8). This species is found much later than *T. tetrophthalmus*. The first specimens were observed during the third week in August and had a peak during the fourth week of August. Specimens last observed were found during the fourth week in September (Figure 4).

The adults of these three species feed first upon the smaller, younger more tender leaves at the upper extremity of the host plants. Feeding first at the tip of a blade, they eat holes a quarter- to three-quarters of an inch from the end of the leaf. Frequently, they may devour all the leaf tissue to the end of the blade, leaving a large U-shaped gouge at the extremity. The flower buds are fed upon as they begin to appear, and finally the emerged flowers themselves are devoured.

Since the grubs are root borers, the females lay their eggs at the base of milkweed stems. In one study, one-fourth of the larvae were found boring into the centers of *A.* sy*riaca* roots (Williams 1941). Depending on their number and the species of milkweed host, they can do considerable damage to the stems. During the course of this study, many stems of *A. syriaca* and *A. meadii* were found dying back and even dead in the middle of the growing season. These were presumed to have been attacked by these boring grubs.

Milkweed leaf-eating beetle (*Labidomera clivicollis* (Chrevolat)
The adults of this species are robust in size and convex in

Table 3. Number of *Tetraopes tetraophthalmus* and *T. femoratus* adults found on *Asclepias* species.

Asclepias Spp.	T. tetraophthalamus No.of Insects Observed on	T. tetraophthalamus No.of Insects per 1000 Stems	T. femoratus No.of Insects Observed on	T. femoratus No.of Insects per 1000 Stems
A. amplexicaulis	1	1.1	0	---
A. exaltata	1	2.2	0	---
A. hirtella	1	1.6	1	1.9
A. incarnata	0	---	2	0.8
A. lanuginosa	1	0.5	2	1.1
A. meadii	3	4.8	1	1.6
A. purpurascens	9	19.5	0	---
A. sullivantii	6	1.5	1	0.3
A. syriaca	149	19.4	9	1.4
A. tuberosa	0	---	1	0.3
A. verticillata	2	0.1	0	---
A. viridiflora	2	4.2	1	2.1
Total	175		18	

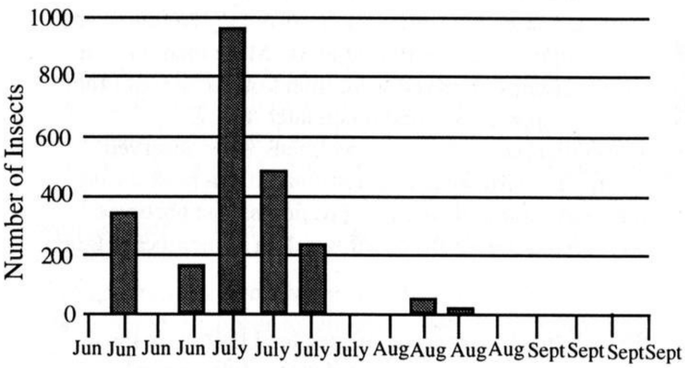

Figure 3. Weekly abundance of *Tetraopes tetraophthalmus* on *Asclepias purpurascens* and *A. syriaca*, adjusted as in text.

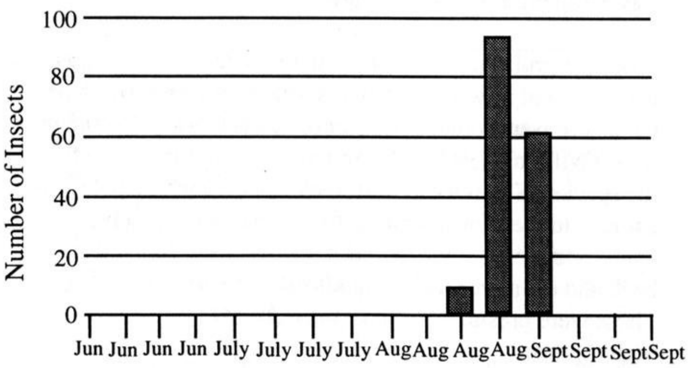

Figure 4. Weekly abundance of *Tetraopes femoratus* on *Asclepias syriaca*, adjusted as in text.

shape. Their head and pronotum are dark bluish black. The elytra are reddish yellow with black markings. The grubs are hump-backed, have a black head, and are slightly pinkish in color.

The adults were found on 5 of the 12 milkweed species studied, showing a preference for A hirtella (4.7 specimens/1000 stems) and *A. incarnata* (4.2/1000) (Table 4). This species was also reported to be very frequent on *A. exaltata* (Wilbur 1976). Seventy-eight percent of the specimens observed were on the leaves with most of the others found on the flowers (Table 8). This species is found throughout the summer from the second week in June to the fourth week in September (Figure 5).

Both adults and grubs can be found together feeding on the leaves. Unless they are especially numerous, they usually cause little damage to the plant.

Common milkweed stem weevil (*Rhyssematus lineaticollis* (Say)

The adults of this species are short, oval, and robust. They are black having a thorax with sides subparallel near the base and marked with strigae that are not oblique and nearly parallel with the medium line. The grubs are white with brown heads.

A second species, *R. annectans* (Casey), is of rare occurrence and was not observed during this study. It is primarily an eastern species near the end of its range in the Chicago area. It differs from *R. lineaticollis* in being slightly smaller, has a thorax with sides converging from base to apex, and is marked with more or less oblique strigae that converge toward the middle.

Table 4. Number of *Labidomera clivicollis* and *Rhyssematus lineaticollis* adults observed on *Asclepias* species.

Asclepias Spp.	Labidomera clivicollis No.of Insects Observed on	Labidomera clivicollis No.of Insects per 1000 Stems	Rhyssematus lineaticollis No.of Insects Observed on	Rhyssematus lineaticollis No.of Insects per 1000 Stems
A. amplexicaulis	0	---	0	---
A. exaltata	0	---	2	4.5
A. hirtella	3	4.7	0	---
A. incarnata	12	4.2	0	---
A. lanuginosa	0	---	0	---
A. meadii	0	---	2	3.2
A. purpurascens	0	---	2	4.3
A. sullivantii	0	---	0	---
A. syriaca	10	1.3	8	1.0
A. tuberosa	2	0.6	1	---
A. verticillata	34	1.1	0	---
A. viridiflora	0		0	---
Total	60		15	

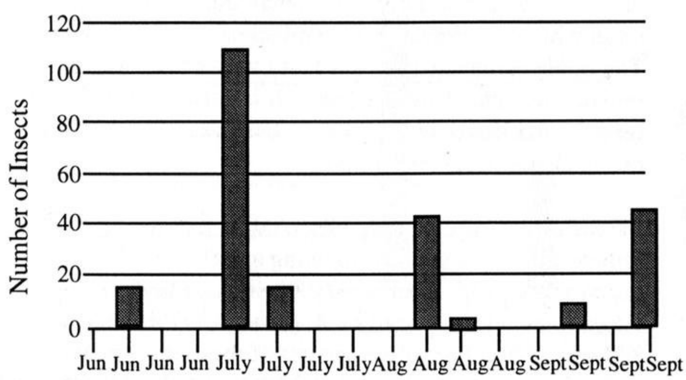

Figure 5. Weekly abundance of *Labidomera clivicollis* on *Asclepias verticillata*, adjusted as in text.

Adults of this species were found on 4 of the 12 milkweed species studied, showing a preference for *A. exaltata* (4.5 specimens/1000 stems) and *A. syriaca* (4.3/1000) (Table 4). In addition, Wilbur (1976) found adults on *A. incarnata, A. tuberosa, A. verticillata*, and *A. viridiflora*. In another study, adults were reported on *A. amplexicaulis* (Price and Willson 1979). Over 90% of the specimens observed were on the stems (Table 8). This species was observed from the end of June to the end of August. The peak is during the first week in June. (Dailey et al. 1978).

The adults are nocturnal and are more likely to be seen after sundown feeding and ovipositing on the stems. When exposed to light they drop to the ground and are difficult to find. The few that are found on the plant during daylight hours are usually observed hiding under the leaves or deep among the flowers of the umbel. During the day most hide in the duff and soil around the milkweed stem.

The grubs were found feeding in the pith of milkweed stems producing a black frass within the center of the stem. There can be up to 26 grubs in a stem. With large numbers, the entire stem can be hollowed out starting from almost the tip of the stem down to the beginning of the root. The grubs, however, do not feed on the roots.

The stems that are hosts to the grubs have vertical slits elongated along the stems produced by adults or ovipositing females. These vertical slits, which are between 1-3 mm long, are slightly opened with dried whitish gray exudate on their periphery sometimes extending down the stem. There can be up to six or seven of these slits on a stem.

Grubs do not pupate within the stems of the host but rather in the soil. They exit the stems presumably through the vertical openings or wounds. The winter is passed in the pupal stage. The adults emerge during the spring and early summer of the following year.

In order to verify the species identity of grubs found in the stems of A. syriaca, the following procedure was carried out. 1) The stems containing full-grown grubs were carefully cut during the third week of July and placed in a bottle of water to prevent wilting. 2) aluminum foil was then placed over the top of the bottle and around the stems. This was to prevent the grubs from falling into the water and drowning. 3) The bottle in turn was placed in an empty aquarium tank to prevent the grubs from escaping if and when they left the interior of the stem. Within a few days most of the grubs had left the stems and fallen into the dry empty tank. They appeared to be very agitated and incessantly crawled around the bottom in an effort to get out. 4) They were then easily collected and placed in a jar with moist earth, into which they bored and pupated. Within four weeks adults were found in the soil and were identified as *Rhyssematus lineaticollis*. These studies were repeated for three consecutive years.

Unless grubs are present in large numbers in the thicker stemmed milkweed species, such as A. sy*riaca*, they cause very little damage to the plant. It appears that they feed mostly on the pith and do not injure the conducting tissues. However, with some of the thinner stemmed milkweeds, such as *A. meadii* and *A. quadrifolia*, grubs feeding in the stem can so weaken the stem as to cause it to collapse with its flower umbels and a large portion of the stem with leaves. Some of this damage may also be caused by the adults puncturing the stem either in feeding or in ovipositing. Approximately 3% of the single terminal umbels of *A. meadii* are toppled in this way.

Butterflies and Moths (Lepidoptera)

Monarch butterfly *(Danaus plexippus* (L.)
This species belongs to the Danaidae or monarch butterflies. Both the adult and larva are familiar to most people. The adults feed on nectar and cause no harm to the plant. They are minor pollinators of *A. incarnata* and *A. tuberosa* (Betz et al. 1994).

Larvae of this species were found on 8 of the 12 milkweed species studied, showing a preference for *A. syriaca* (4.0 specimens/1000 stems) and to a lesser extent for *A. tuberosa* (3.4)/1000 and *A. sullivantii* (3.5/1000) (Table 5). Larvae were also reported on *A. viridiflora* (Wilbur 1976) and on *A. amplexicaulis* (Price and Willson 1979). Over 84% of the larvae were observed on the leaves (Table 8). Few of these appear in June but most appear during the third week of August. The last specimens were seen during the second week in September (Figure 6).

The larvae of this species feed principally on leaves, but will also eat buds and flowers. Usually there is only one larva to be found on a stem; however, infrequently a number of larvae of the same or different instars can be found feeding on the same stem. Since the larvae have ravenous appetites they can cause considerable damage if they are numerous on a stem. Larvae are especially damaging to some of the smaller species of milkweed,

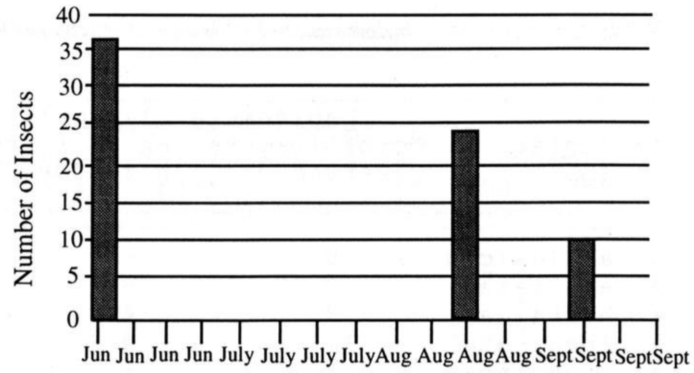

Figure 6. Weekly abundance of *Danaus plexippus* on *Asclepias sullivanti* and *A. syriaca*, adjusted as in text.

such as *A. meadii* and *A. quadrifolia*. There is a tendency for eggs to be laid on younger plants. Two or three first instars can wreak havoc in a flat of milkweed seedlings.

Orange-margined milkweed moth (*Cycnia tenera* Hubner)
This species is a member of the Arctiidae. Formerly, it was known as *Pygarctia eglenensis*. The adult, which is seldom collected, is a relatively small dull yellow grayish moth with black dorsal and lateral spots on its abdomen. The easily recognized larva is hairy with a deep reddish brown color and an orange head. It is easily detected as it feeds on the leaves of milkweed. They are very conspicuous in clones of *A. verticillata*.

Larvae of this species were observed on 8 of the 12 milkweed species studied, showing a preference for *A. purpurascens* (8.7 specimens/1000 stems) (Table 5). Larvae were also reported on *A. incarnata* (Price and Willson 1979). Forty-five percent of these specimens were observed on the leaves, and 27.5% on the flowers (Table 8). A few specimens were first seen during the second week in June, and the largest number observed during the second week of August. The last specimen was observed during the second week of September (Figure 7).

The larvae feed on the leaves of milkweeds. Since there is usually only a single individual to a plant, they cause very little damage.

Harlequin caterpillar moth, milkweed tussock moth (*Euchaetias egle* (Drury)
This species is also a member of the Arctiidae. Like *Cycnia tenera*, the adult is rarely collected. Its wings are of a dull grayish color and the body is light orange with black dots on its dorsal surface. Its larvae are conspicuously colored with tufts of black and orange hairs projecting from their bodies; their heads are black. Larvae of this species were found on 2 of the 12 milk-

Table 5. Number of *Danaus plexippus* and *Cyncia tenera* larvae observed on *Asclepias* species.

Asclepias Spp.	Danaus plexippus No.of Insects Observed on	Danaus plexippus No.of Insects per 1000 Stems	Cycnia tenera No.of Insects Observed on	Cycnia tenera No.of Insects per 1000 Stems
A. amplexicaulis	0	---	0	---
A. exaltata	0	---	0	---
A. hirtella	0	---	0	---
A. incarnata	5	1.8	0	---
A. lanuginosa	2	1.1	2	1.1
A. meadii	1	1.6	2	3.2
A. purpurascens	1	2.2	4	8.7
A. sullivantii	14	3.5	1	0.3
A. syriaca	31	4.0	6	0.8
A. tuberosa	11	3.4	7	2.1
A. verticillata	3	0.1	34	1.1
A. viridiflora	0	---	2	4.2
Total	68		58	

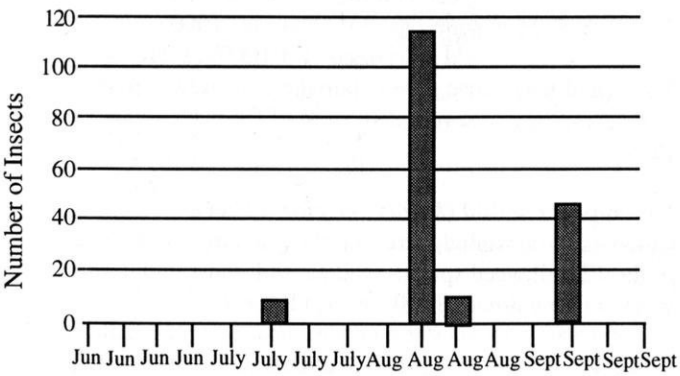

Figure 7. Weekly abundance of *Cycnia tenera* on *Asclepias purpurascens* and *A. viridiflora*, adjusted as in text.

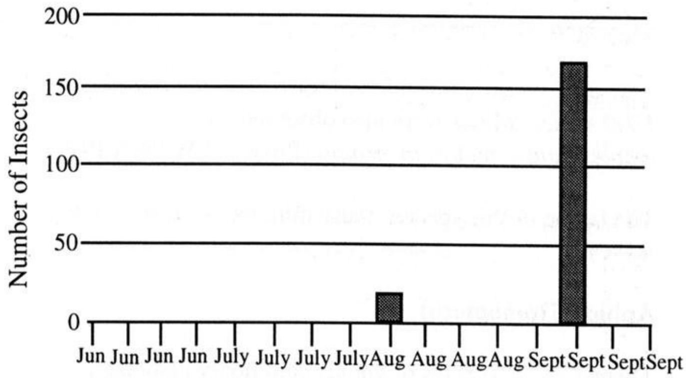

Figure 8. Weekly abundance of *Euchaetias egle* on *Asclepias syriaca*, adjusted as in text.

weed species studied, showing a preference for *A. exaltata* (51.2 specimens/1000 stems) and *A. syriacaa* (22.1 specimens/1000 stems) (Table 6). Larvae were also observed on *A. incarnata* (Price and Willson 1979). All of these larvae were found on the undersides of the leaves in tightly knit clusters of about a dozen or more individuals (Table 8). Few specimens were found during the first week of August; the peak population occurred during the second week of September (Figure 8).

The larvae feed on the leaves; whereas, the adults feed on flower nectar. There are two broods per season. Damage caused by the larvae depends on the number present. A few cause very little damage to a stem. However, large numbers can cause severe damage to the stem. A cluster of approximately 50 caterpillars on a mature milkweed stem will completely defoliate and skeletonize a stem down to the root.

It is interesting to note that occasionally isolated specimens of this species were observed on the leaves of dogbane (*Apocynum sibiricum*).

Flies (Diptera)

Milkweed leaf-miner fly (*Liriomyza asclepiadis* Spencer)
The maggot of this tiny fly feeds on the mesphyll tissue of leaves leaving only the upper and lower epidermal tissues to form the characteristic transparent bloche mines (Spencer 1986).

Neither the maggot nor the adult fly was found. The oval-shaped blotched mines produced by these larvae were found on 3 of the 12 milkweed species—*A. purpurascens, A. sullivantii*, and *A. syriaca*. The maggots showed a preference for *A. syriaca* with mines being found on 14.7/

Table 6. Number of *Euchaetias egle* larvae observed on *Asclepias* species.

Asclepias Spp.	Euchaetias egle No.of Insects Observed on	No.of Insects per 1000 Stems
A. amplexicaulis	0	----
A. exaltata	23	51.2
A. hirtella	1	1.6
A. incarnata	0	----
A. lanuginosa	0	----
A. meadii	0	----
A. purpurascens	0	----
A. sullivantii	1	0.3
A. syriaca	162	21.1
A. tuberosa	0	----
A. verticillata	0	----
A. viridiflora	-0	----
Total	187	

1000 stems. Mines were also observed on *A. amplexicaulis*, and *A. incarnata* (Price and Willson 1979).

The larvae of this species cause minimal damage to the leaves.

Aphids (Homoptera)

There are five species of aphids commonly associated with milkweeds. Colonies of them are found on the upper parts of the plant where they feeding on young stems and leaves by piercing them with their beaks and then sucking the sap. The removal of sap damages the plant cells, causing a characteristic curling and deformation of the leaves and stems. In severe infestations, the upper parts of the plant are killed. Aphids are especially preyed upon by the larvae and adults of ladybird beetles, lacewing larvae, and syrphid fly maggots. A characteristic ladybird beetle, closely associated with aphids on milkweeds, is *Brachacantha ursina* Fabricus.

It would have been time consuming to check each milkweed stem in order to observe the few isolated aphids that might be on it. For that reason, a colony of approximately 50 to 100 individuals, which could be easily seen, was taken to be the unit in this study (Dichtl 1967).

The peak of aphid infestation occurred during June. Only 4 of the 12 milkweed species studied were parasitized by aphid colonies. They were: *A. syriaca* (12.9% of the plants during June), *A. sullivantii* (6.6%) *A. viridiflora* (1.0%), and *A. hirtella* (0.5%).

Yellow milkweed or oleander aphid (*Aphis nerii* Boyer de Fonscolombe), formerly as (*A. asclepiadis* Fitch).

Colonies of this aphid were found on 4 of the 12 milkweed species studied and were easily seen because of their bright yellow color covering the upper leaves, stems, and pods. There is a preference for *A. incarnata* (10.6 colonies/1000 stems), *A. hirtella* (7.8/1000), *A. sullivantii* (7.5/1000) and *A. syriaca* (6.8/1000) (Table 7).

Large colonies of this aphid are sometimes found on *A. incarnata* and *A. hirtella,* covering the upper parts of the stem, causing extensive damage to the growing tip, leaves, and pods.

Black aphid (*Aphis rumicis* L.) Colonies of this aphid were found on the upper parts of 2 of the 12 milkweed species studied. They were *A. sullivantii* (1.2 colonies/1000 stems) and *A. syriaca* (1.3/1000) (Table 7). This aphid may cause severe damage to the upper parts of stems, resulting in severe distortion of the leaves and stem.

Green peach aphid (*Myzus persciae* Sulzer). Colonies of this aphid were found on the upper parts of 3 of the 12 milkweed species studied with most found on *A. syriaca* (3.5 colonies/1000 stems) (Table 7).

This species is usually found in a mutualistic relationship with certain species of ants. The aphid produces a sugary, energy-rich liquid called honeydew on which the ants feed. The ants in turn protect the aphids from predatory insects. This aphid is very common on many garden and crop plants and is involved in the transfer of plant viral diseases.

Cotton or **melon aphid** (*Aphis gossypii* Glover). Colonies of this small green aphid with dark cornicles were found on the upper parts of 2 of the 12 milkweed species studied, with most found on *A. exaltata* (Table 7). This species is common on many garden and crop plants.

Red aphid (*Macrosiphum redbeckiae* Fitch). Colonies of this relatively large red aphid were found on the upper parts of *A. syriaca* (0.5 colonies/1000). It is common on wild golden glow (*Rudbeckia laciniata*), a plant of shaded or partly shaded flood plains found along streams and rivers (Table 7).

Thrips (Thysanoptera)

Thrips are minute, slender-bodied insects (0.5–5.0 mm in

Table 7. Number of aphid colonies (50–150 individuals) observed on *Asclepias* species.

Asclepias	Aphis nerii (yellow milkweed or oleander aphid) No.of Colonies Observed on	No.of Colonies per 1000 Stems	Aphis gossypii (cotton or melon aphid) No.of Colonies Observed on	No.of Colonies per 1000 Stems
A. exaltata	1	2.2	1	7.0
A. hirtella	5	7,8	0	---
A. incarnata	30	10.6	0	---
A. sullivantii	30	7.5	0	---
A. syriaca	52	6.8	1	0.9
A. viridiflora	0	---	0	---
Total	118		2	
	Aphis rumicis (black aphid)		**Myzus persciae (green peach aphid)**	
A. exaltata	0	---	0	---
A. hirtella	0	---	0	---
A. sullivantii	5	1.2	8	2.0
A. syriaca	13	1.7	45	5.9
A. tuberosa	1	0.3	0	---
A. viridiflora	0	---	1	2.1
Total	19		54	
	Macrosiphum rudbeckiae (red aphid)			
A. exaltata	0	---		
A. hirtella	0	---		
A. sullivantii	0	---		
A. syriaca	4	0.5		
A. viridiflora	0	----		
Total	4			

Table 8. Parts of plant on which insects were observed.

Insect Species	Leaves % on	Stems % on	Flowers % on	Pods % on	Roots % on
Cycnia tenera (larvae)	45.0	5.0	27.5	15.0	0.0
Danaus plexippus (larvae)	84.5	10.3	3.4	3.4	0.0
Euchaetias egle (larvae)	100.0	0.0	0.0	0.0	0.0
Labidomera clivicollis (a/l)	78.0	0.0	22.0	0.0	0.0
Lygaeus kalmii (a/n)	20.0	7.7	9.2	63.0	0.0
Oncopeltus fasciatus (a/n)	10.7	4.0	10.0	75.0	0.0
Rhyssematus lineaticollis (a)	4.5	90.1	4.5	0.0	0.0
Rhyssematus lineaticollis (l)	0.0	100.0	0.0	0.0	0.0
Tetraopes femoratus (a)	94.2	0.0	0.0	5.9	0.0
Tetraopes femoratus (l)	0.0	0.0	0.0	0.0	100.0
Tetraopes tetraophthalmus (a)	80.2	4.6	20.9	0.0	0.0
Tetraopes tetraophthalmus (l)	0.0	0.0	0.0	0.0	100.0

*a= adult; l= larva; n= nymph

length) with four wings. These wings are long and narrow, with few or no veins, and fringed with long hairs. The nymphs are wingless. They have a piercing proboscis or beak with which they suck plants juices.

Eastern flower thrip (*Frankliniellia tritici* (Fitch). These tiny slender yellow and orange thrips, which can be seem with a hand-lens, were found among the flower umbels of *A. syriaca*. They were also seen on the flowers of *A. meadii*. Because of their small size and low numbers, they cause very little damage to mature milkweed plants. However, they can damage young milkweed seedings as shown by the curl and distortion of the leaves.

DISCUSSION

Less Abundant *Asclepias* Herbivores

There were other insects that were occasionally found on milkweeds. *Lygaeus bicrusis*, a relatively small hemipteran, was found once on *A. purpurascens* flowers and once on the flowers of *A. syriaca*. A forked-tailed bush katydid (*Scudderia furcata* Brenner) was found feeding on the flowers of *A. amplexicaulis*. A number of individuals of a small weevil species (*Gymnetron tetrum* (Fabricus) were found among the flowers of *A. syriaca.*

Occasionally, other insect herbivores associated with milkweeds are reported in the literature. They include (a) the mirid or plant-eating bugs *Ilnacora divisia* (Knight) and *Macrolophus brevicornis* (Fieber); (b) the chrysomelid leaf-eating beetles *Babia quadrigutta* (Olivier) and milkweed tortoise beetle *Chelymorpha cassidea* (Fabricus); and (c) the melloid blister beetle *Epicauta vittata* (Fabricus). Although 132 species of beetles (*Coleoptera)* have been collected on *A. syriaca* (Dailey et al. 1978), most of these species were not obligate milkweed herbivores. Some were predators feeding on milkweed herbivores, such as the milkweed ladybird beetle (*Brachyacantha ursina)*. Others were general feeding herbivores, and still others were just perched on the milkweed.

Warning Coloration of *Asclepias* Herbivores

Many milkweed herbivores are brightly colored in black and orange/yellow. It has been theorized that the reason for this coloration is that these colors are aposematic, that is, they convey a warning to predators, especially birds, that their potential prey is bad-tasting or even poisonous. This toxicity is due to the cardiac glycosides which have been obtained by insects from feeding on milkweeds. The tight orange and black clusters of the harlequin caterpillars (*Euchaetias egle*) observed hiding under milkweed leaves and the clusters of the large milkweed bug nymphs (*Oncopeltus fasciatus*) found on pods are probably an attempt to maximize the use of these aposematic colors.

It is interesting to note that the adult common milkweed stem weevil (*Rhyssematus lineaticollis*) is all black with no red or orange markings. It would seem that this is related to the fact that the weevil tends to be nocturnal and receives little or no benefit in having aposematic colors.

Populations and Herbivore Preferences

It is probable that some herbivore preferences are based the on need to provide an adequate food supply for their developing young. For this reason, it is important that females oviposit on potential host plants that can support relatively large healthy populations of offspring. For the common milkweed weevil (*Rhyssematus lineaticollis*) this means ovipositing on the thicker stemmed milkweeds, such as *A. amplexicaulis, A. exaltata, A. purpurascens, A. sullivantii*, and *A. syriaca*. These produce relatively large amounts of pith on which the grubs feed. To oviposit on the thin-stemmed milkweeds with small amounts of pith, such *A. meadii* and *A. quadrifolia*, can at best result in a stunted grub or two.

This is probably also true for the milkweed long-horned boring beetles (*Tetraopes tetropthamus* and *T. femoratus*) for which is it necessary for the females to lay their eggs at the base of a large robust milkweed species having thick roots. It is interesting to note that the three specimens of *T. tetraopthalmus* adults observed on *A. meadii* were all small-sized, which no doubt was caused by the relatively small food supply of the root-stock on which the grubs had fed.

In many cases, it is difficult to draw conclusions on the reasons for the preferences shown by the milkweed herbivores for host plants. This is in part due to 1) the low populations of herbivores, 2) the fragmentation of the herbivore populations, and 3) the large variations in the populations of the species of milkweeds and their fragmentation.

In general, the mean populations of most species of herbivores observed in this study were low, i.e., approximately 2 to 7 specimens per 1000 stems. These numbers are somewhat lower than those reported by Price and Willson (1979). Also these mean populations for milkweed herbivores are much lower than many of the mean populations of herbivores reported for many other genera of plants. For example, the chrysomelid beetle *Trirhabda canadensis* (Kirby) produces large populations on tall goldenrod (*Solidago altissima*) in which almost every stem carries enough beetles to cause considerable damage to the leaves (personal observations).

Not only are the populations of these milkweed herbivores low, they are not uniform in their distribution. While there were some widely scattered specimens, there was a tendency for clusters of them to occur locally or in isolated pockets. This was especially true of insects, such as the aphids. A few isolated clones of *A. syriaca* would have a large proportion of the stems and upper leaves covered with green peach aphids (*Myzus persicae*); whereas, the majority of *A. syriaca* had few or none at all. The same was true of the milkweed aphid *(Aphis nerii)* on *A. incarnata* and *A. syriaca.* The clones of *A. syriaca* with stems infested with the larvae of the common milkweed weevil (*Rhyssematus lineaticollis*), and clones of *A. syriaca* with leaves which were hosts to the milkweed leaf miner fly (*Liriomyza asclepiadis*) were similarly localized.

In this study, over 35,000 stems of 12 species of Asclepias were observed for the presence of insect herbivores. The number of stems observed were not divided equally among these 12 species. Rather 92% of the stems observed belonged to four species: 1) common milkweed (*A. syriaca*), 2) whorled milkweed (*A. verticillata*), 3) prairie milkweed (*A. sullivantii*), and 4) butterfly weed (*A. tuberosa).* This disparity was not planned, but represents the populations available for study.

Present populations do not necessarily represent former relative abundance. Because of the widespread disturbance of natural habitats, a few species, such as A. syriaca, are probably more common today than they were in presettlement times. *A. syriaca* is especially abundant in waste places, old fields, agricultural fields, railroad rights-of-way, and even thickets. It is the common milkweed in the majority of studies on milkweeds. It would have been easily possible for *A. syriaca* to account for 95% of the plant stems observed. This would have modified the data in comparison to what they may have been in the past. During this study many large clones of *A. syriaca* were deliberately not observed because time was better spent searching for the rarer milkweed species with herbivore populations. All 18 of the herbivores of this study were observed on *A. syriaca.* None of the other 11 milkweed species came close to having this number of herbivores.

In presettlement times it is quite possible that *A. syriaca* may have been less abundant in climax or near-climax communities where disturbance was probably at a minimum. Other, now rarer species, such as, *A. exaltata, purpurascens, A. sullivantii,* and even the prairie-restricted *A. meadii*, were undoubtedly more abundant and provided more of the food source for many of the milkweed herbivores.

An interesting observation was made when 6 specimens each of 15 species of milkweeds (all 12 of the ones included in this paper, plus A. ovalifolia, *A. perennis, A. quadrifolia* and *A. variegata*) were grown from seeds and planted in the same plot next to one another. When a few specimens of common milkweed weevils (*Rhyssematus lineaticollis*) were observed in this milkweed colony of mixed species, they were feeding and ovipositing on *A. purpurascens* and not on *A. syriaca* (personal observation). This suggests that patterns of feeding and egg laying in the past may have been different from today for some herbivores.

The Life History of Milkweed Weevils

The discrepancies in the life histories of milkweed weevils (*Rhyssematus spp.*) need to be resolved. In this study, the larvae of *R. lineaticollis* were found feeding on the pith within milkweed stems, leaving the stem to pupate and metamorphose in the ground. This observation is in accord with the results of Wilbur (1976).

Notwithstanding this fact, most reports in the literature have the larvae of *Rhyssematus lineaticollis* feeding on developing seeds in the pods of *A. amplexicaulis* (Price and Willson 1979), *A. quadrifolia* (Chaplin and Walker 1982), *A. syriaca* (Weiss and Dickerson 1921), *A. incarnata* (Webster 1889–890), and several species of *Asclepias* (Blatchley 1916). In this regard, it should be noted that when 1672 pods belonging to 18 species of *Asclepias* spp. were opened and studied, none contained any weevil larvae (Betz and Lamp 1992).

One explanation is that the two species, *R. lineaticollis* and *R. annectens* have different life histories. This study indicates that *R. lineaticollis* has one generation a year. The grubs feed on pith within the milkweed stems of a number of *Asclepias* species. When fully developed they leave the stem, burrow into the ground, and pupate. The following June the adults leave the ground, mate, and begin another generation.

On the other hand, *R. annectens* has two generations a year and is associated only with *A. incarnata* and/or *A. incarnata pulchra.* The grubs of the first generation feed in the stem like the those of *R. lineaticollis*, but pupate within the stem rather than the ground. The adults of this first generation then oviposit in the developing folicles (pods) with the grubs feeding on the developing seeds. Afterwards the grubs leave the pods and pupate in the ground to form the adults for the following year (Weiss and Dickerson 1921).

A second explanation is that the species in question may have been misidentified. *R. lineaticollis* is recorded as breeding "in the seed pods of *Asclepias incarnata*, the larva feeding upon the seeds and transforming to the adult in late autumn" (Webster 1889–1890). However, Weiss and Dickerson (1921) noted that *Rhyssematus lineaticollis* of Webster "may possibly refer to *Rhyssematus annectans* Casey, a related species which we have found breeding in the seed pods of *Asclepias pulchra* (*incarnata*)." In this same paper the species which they called *R. annectans* was observed only on *A. pulchra* and had two generations per year. The larvae of the first generation fed in the stems; the larvae of the second generation fed on the seeds in pods. During this second generation, "the larvae feed on the developing seeds usually in the center of the mass and when full grown pupate in cells composed of frass, etc., in the middle basal portion of the seed cluster." During the first part of October many pupae were found. By this time all the infested pods had split open on one side exposing the seeds; the seeds however do not disperse being webbed up and held together. During the first ten days of October the beetles leave the infested seeds and disappear" (Weiss and Dickerson 1921).

A third explanation may be that some of the reports in the scientific literature that *R. lineaticollis* feed in the pods are wrong and are not backed up by more intensive life-cycle studies. Perhaps it may have been an originally flawed observational study that has been passed on through the years in various journals.

A fourth, but unlikely, explanation is that there actually may be a population of *R. lineaticollis* whose larvae feed in the pods.

CONCLUSIONS

A better understanding of the relationships among insect herbivores and their milkweed hosts can be achieved by including a larger number of the rarer species of *Asclepias* species than is usually the case.

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TWO DECADES OF PRAIRIE RESTORATION AT FERMILAB BATAVIA, ILLINOIS

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ABSTRACT: In the spring of 1975 seeds of 70 prairie species, hand-collected from remnant prairies within a 50-mile radius of Fermilab, were planted by Nisbet drill in a 3.9 ha (9.6 acres) of tilled agricultural soil within the Fermilab accelerator ring. Since that time, there have been 23 additional plantings both inside and outside the ring. The total area seeded to prairie is approximately 405 ha (1000 acres). During these past two decades a method of successional restoration has been developed. In this method, the seeds of early successional species having wide ecological tolerances, designated the **prairie matrix**, are drilled into recently cultivated ground. Within three years this prairie matrix provides an adequate fuel load capable of being burned. This initiates changes in the biological and physical structure of the soil necessary for the introduction and successful entry of higher successional prairie species having narrower ecological tolerances into the system. Continuous observations of these tracts have provided valuable information on large-scale prairie restoration, which in turn has led to: 1) the use of different and more efficient agricultural equipment; 2) changes in the methods of collecting, cleaning, and sowing of seed; 3) an increased use of both autumn and spring burns; 4) the development of new methods for the enrichment of plantings; and 5) studies on the possible use of mycorrhizal fungi inocula to hasten the establishment of higher successional species. In addition to the prairie restoration project, efforts are also being made to increase the species diversity of remnant wetlands and woods at Fermilab.

Key words: prairie, restoration, Fermilab

INTRODUCTION

During the autumn of 1974, approximately 181.2 kg (400 lb) of mixed prairie seeds (70 species) were hand-collected from remnant prairies found within 80.5 km (50 mi) of Fermilab. These were cleaned, and then stratified at approximately 5°C (40° F) for two months. In the first week of June 1975, these seeds were planted, using a Nesbit drill, into 3.9 ha (9.6 acres) of previously plowed and disked previously cultivated closely related soil types: Mundelein silt loam (Aquic Argiudoll), Wauconda silt loam (Udollic Ochraqualf), and Drummer silty clay loam (Typic Haplaquoll) located within the accelerator ring at Fermilab. During the first decade of restoration a total of 156 ha (385 acres), (mostly within the accelerator ring) were planted. Over this time there were a number of changes made in the methods used for ground cultivation, for planting, and for species enrichment of the prairie tracts subsequent to the initial planting (Betz 1986).

During the second decade an additional 239 ha (590 acres) of land were planted. In all, there have been 24 plantings (spring and autumn), bringing the total area to approximately 405 ha (1000 acres) both in and outside of the accelerator ring, (Table 1). Forty percent is within the accelerator ring and 60% outside.

Of the 656 species of vascular plants found at Fermilab, 147 are prairie species, or 22.4% of the total. At present 13 prairie species, such as, Indian paintbrush (*Castilleja coccinea)*, New Jersey tea (*Ceanothus americanus),* eastern prairie fringed orchid (*Habenaria leucophaea*), rough white lettuce (*Prenanthes aspera)*, and eared false foxglove (*Tomanthera auricula)* have not been found but eventually will be introduced.

There are 120 wet meadow species, or 18.3% of the total. At present there are 12 wet meadow species, such as, sweet flag (*Acorus clamus*) and marsh shield fern (*Dryopteris thelypteris pubescens*), which are not found at Fermilab but will be added.

The combined number of prairie and wet meadow species found in the 21 prairie plots varies from 16 in Plot 20, most recently planted, to 157 in Plot 6, which is relatively large with a variable topography. However, the richest in

Table 1. Size of prairie plots; when planted and number of species.

Plot #	When Planted	Hectares	Acres	# of Prairie & Wet Meadow Species
1	Spring 1975	3.6	9	89
2	Spring 1975	4.5	11	74
3	Spring 1977	11.7	29	83
4	Fall 1977	6.5	16	60
5	Fall 1978	4.5	11	52
6	Fall 1979	24.3	60	157
7	Spring 1981	6.9	17	52
8	Fall 1981	18.6	46	76
9	Fall 1982	22.7	56	97
10	Spring 1983	21.5	53	90
11	Spring 1984	13.0	32	110
12	Spring 1984	13.4	33	101
13	Spring 1985	19.0	47	122
14	Spring 1985	7.7	19	77
15	Spring 1986	20.2	50	84
16	Summer 1988	27.9	60	56
A-Tract	Summer 1989	30.4	75	21
17	Summer 1990	34.0	84	58
CA-2 Tract	Summer 1990	28.7	71	23
18	Spring 1992	4.0	10	26
A-Tract #2	Spring 1992	28.3	70	6
19	Summer 1993	22.3	55	12
20	Spring 1994	16.2	40	16
21	Spring 1995	14.2	35	—
Total		404.1	998	

terms of prairie species diversity is Plot 1 with 90 species (Table 1).

During the second decade of prairie restoration, efforts were also made to restore the degraded remnant wetland and woodland communities to their more natural states characteristic of the presettlement Illinois landscape. The number of native trees, shrubs, and herbaceous plants found in these woodlands is 196, or 30.0% of the total species present at Fermilab. One hundred and sixty-eight species of herbaceous non-native plants occur in these areas, or 25.6% of the total at the lab. In addition, the 25 species of woody exotics make up 3.8% of the total species found at Fermilab.

While herbicides are occasionally used to control non-native plants in a few places at Fermilab, such as, along roadsides and around buildings, they are not generally used in the restoration of the prairie. Rather these non-native plants are controlled and eliminated by the ecological competitiveness of the prairie species in areas repeatedly burned.

The Concept of Successional Restoration

"Successional restoration" is the method being used to restore the prairie at Fermilab on former agricultural fields. This involves an initial planting, using aggressive species that have wide ecological tolerances, which grow well on abandoned agricultural fields. Collectively, these species are designated as the prairie matrix (Betz 1986). The species used for this prairie matrix compete with and eventually eliminate most weedy species. They also provide an adequate fuel load capable of sustaining a fire within three years after a site has been initially planted. Associated changes in the biological and physical structure of the soil help prepare the way for the successful introduction of plants of the later successional species.

The species diversity is increased by introducing species with narrower ecological tolerances, characteristic of later successional stages, only after the species of the prairie matrix are well established

The species of the prairie matrix used originally included 25 species or approximately 10% of the prairie flora (Betz 1986). However, based on the experiences of the past decade (1986-1996), this number has been increased to 36 or about 24% of the original prairie flora (Table 2). Three species were removed from use in the prairie matrix and added to the second successional stage. They are prairie coreopsis (*Coreopsis palmata*), Illinois tick trefoil (*Desmodium illinoense*), and purple coneflower (*Echinacea pallida*). Surprisingly, experience also showed that smooth beard tongue (*Penstemon calycosus*) and foxglove beard tongue (*P. digitalis*), originally included in the second stage, could be successfully used in the prairie matrix.

The number of species now included for the list of the second successional stage (Stage 2) is 48 (Table 3). Tentatively, a list of species designated as Stage 3 includes 16 species (Table 4), and 9 species are proposed for Stage 4 (Table 5).

Observations over the past 20 years have shown that it takes approximately 2 to 3 years for the prairie matrix to establish itself. Big bluestem grass (*Andropogon gerardii*) and Indian grass (*Sorghastrum nutans*) become dominant on mesic soil, and prairie cord grass (*Spartina pectinata*) dominated on wet soils. Switch grass (*Panicum virgatum*) is not a dominant, but has a minor presence in the developing prairie. The two other prominent prairie grasses, little bluestem (*Andropogon scoparius*) and prairie dropseed (*Sporobolus heterolepis*) appear to be species characteristic of the second or even the third stage.

It is interesting that the spontaneous introduction and subsequent dominance of asters (*Aster*) may be correlated with different successional stages. These stages and associated asters are as follows: a) weedy abandoned agricultural field—hairy aster (*A. pilosus*); b) Stage 1—Drummond's aster (*A. sagittifolius drummondii*); c) Stage 2—heath aster (*A. ericoides*) and New England aster (*A. novae-angliae*); d) Stage 3—sky-blue aster (*A. azureus*) and smooth blue aster (*A. laevis*).

With few exceptions, the sequence of species from Stage 1 to Stage 4 is similar to the sequence proposed by Peter Schramm (1990). However, there are differences in what constitutes a stage. Our Stage 1 is a combination of Schramm's Stage I (Initial Downgrow Weedy Stage) and Stage II (Intense Competitive, Stand Establishment Stage). Our Stage 2 is similar to Schramm's Stage III (Closeout Stage). Our Stage 3 and Stage 4 are combined into Schramm's Stage IV (Long-term Adjustment Stage).

METHODS

Harvesting Seed of the Prairie Matrix

Seed of the prairie matrix is harvested by use of a self-propelled combine. Approximately 8000 to 10,000 pounds of uncleaned seed are typically collected each year from tracts with earlier plantings of prairie matrix. In 1989 a record of over 13,000 lbs were collected. However, in some years it is necessary to harvest matrix seed from more recent tracts in order to collect seed for plants, such as Indian grass (*Sorghastrum nutans*), yellow cone flower (*Ratibida pinnata*), and showy tick trefoil (*Desmodium canadense*) whose populations quickly decrease under competition in later stage plantings.

Table 2. Prairie species of the first stage.

Allium canadense (wild onion)
Allium cernuum (nodding wild onion)
Andropogon gerardii (big bluestem grass)
Aster sagittifolius drummondii (Drummond's aster)
Baptisia leucantha (white wild indigo)
Coreopsis tripteris (tall coreopsis)
Desmodium canadense (showy tick-trefoil)
Elymus canadensis (Canadian wild rye)
Helianthus mollis (downy sunflower)
Heliopsis helianthoides (false sunflower)
Lespedeza capitata (round-headed bush clover)
Monarda fistulosa (wild bergamot)
Panicum virginicum (switch grass)
Parthenium integrifolium (wild quinine)
Penstemon calycosus/digitalis (smooth/foxglove breard tongue)
Pycnanthemum virginianum (common mint)
Ratibida pinnata (yellow coneflower)
Rudbeckia hirta (black-eyed Susan)
Rudbeckia subtomentosa (sweet black-eyed Susan)
Senecio paurperculus balsamitae (balsam ragwort)
Silphium integrifolium (rosin weed)
Silphium lacinatum (compass plant)
Silphium terebinthinaceum (prairie dock)
Solidago gigantea (late-flowering goldenrod)
Solidago graminifolia (narrow-leaved grassleaved goldenrod)
Solidago gymnospermoides (wide-leaved grassleaved goldenrod)
Solidago juncea (early goldenrod)
Solidago nemoralis (gray goldenrod)
Solidago riddellii (Riddell's goldenrod)
Solidago rigida (stiff goldenrod)
Sorghastrum nutans (Indian grass)
Spartina pectinata (prairie cord grass)
Thalictrum dasycarpum (purple meadow rue)
Thalictrum revolution (waxy meadow rue)
Vernonia fasciculata (common ironweed)
Zizia aurea (golden Alexanders)

Table 3. Prairie species of the second stage (proposed).

Agalinis tenuifolia (slender false foxglove)
Andropogon scoparius (little bluestem)
Anemone canadensis (Canadian anemone)
Anemone cylindrica (thimbleweed)
Asclepias tuberosa (butterflyweed)
Asclepias sullivantii (prairie milkweed)
Aster novae-angliae (New England aster)
Aster ericoides (heath aster)
Cacalia plantaginea (Indian plantain)
Carex bicknellii (prairie sedge)
Cicuta maculata (water hemlock)
Comandra umbellata (false toadflax)
Coreopsis palmata (prairie coreopsis)
Desmodium illinoense (Illinois tick-trefoil)
Dodecatheon meadia (shooting stars)
Echinacea pallida (purple coneflower)
Eryngium yuccifolium (rattlesnake master)
Euphorbia corollata (flowering spurge)
Galium boreale (northern bedstraw)
Galium obtusum (wild madder)
Gentiana andrewsii (bottle gentian)
Gentiana flavida (yellow gentian)
Gentiana quinquefolia (stiff gentian)
Helianthus rigidus (prairie sunflower)
Krigia biflora (false dandelion)
Lathyrus palustris (marsh vetchling)
Liatris pycnostachya (prairie blazing star)
Liatris spicata (marsh blazing star)
Liatris aspera (rough blazing star)
Lobelia spicata (pale-spiked lobelia)
Oxypolis rigidior (cowbane)
Pedicularis canadensis (prairie betony)
Pedicularis lanceolata (marsh betony)
Petalostemum candidum (white prairie clover)
Petalostemum purpureum (purple prairie clover)
Phlox glaberrima interior (marsh phlox)
Phlox pilosa (prairie phlox)
Physostegia virginiana (false dragonhead)
Polytaenia nuttallii (prairie parsley)
Potentilla arguta (prairie cinquefoil)
Prenanthes aspera (rough white lettuce)
Prenanthes racemosa (glaucus white lettuce)
Psoralea tenuifolia (scurfy pea)
Salix humilis (prairie willow)
Sisyrichium albidum (blue eyed-grass)
Tradescantia ohiensis (common spiderwort)
Veronicastrum virginicum (Culver's root)
Vicia americana (American vetch)

The harvested uncleaned matrix seed is transferred mechanically to a truck and hauled to a large barn where it is mixed and spread out on the floor to a depth of about ten inches to dry. For a number of weeks thereafter, the seed periodically is turned over to enhance drying while also preventing the heat from reaching a kindling point and causing a fire. After drying, the seed is stored on the barn floor over winter and is used for sowing tracts in the late spring. The seed is not cleaned in any way and contains approximately one-third chaff.

Method of Soil Preparation

The plot to be planted is plowed and disked during the autumn of the previous year. If required, clumps of soil are broken up using a cultipacker with the tines down. This is followed by further disking. In the spring of the planting year a further disking is usually done just before planting in order to destroy most of the emerging weed flora which could inhibit the young matrix seedlings.

Table 4. Prairie plants of the third stage (proposed).

Amorpha canaescens (lead plant)
Asclepias hirtella (tall green milkweed)
Asclepias viridiflora (short green milkweed)
Aster azureus (sky-blue aster)
Aster laevis (smooth aster)
Baptisia leucophaea (cream wild indigo)
Bromus kalmii (Kalm's brome grass)
Chelone glabra (turtlehead)
Heuchera richardsonii grayana (alum root)
Lithospermum canescens (hoary puccoon)
Lysimachia quadriflora (narrow-leaved loosestrife)
Panicum leibergii (prairie panic grass)
Polygala senega (Seneca snakeroot)
Spiranthes magnicamporum (ladies' tresses orchid)
Sporobolus heterolepis (prairie dropseed)
Valeriana ciliata (common valerian)

Table 5. Prairie plants of the fourth stage (tentative).

Asclepias meadii (Mead's milkweed)
Cypripedium candidum (white ladies's slipper)
Gentiana puberulenta (prairie gentian)
Habenaria leucophaea (white fringed orchid)
Hypoxis hirsuta (yellow star grass)
Lilium philadelphicum andinum (prairie lily)
Oxalis violacea (purple wood sorrel)
Scutellaria parvula leonardii (small skullcap)
Viola pedatifida (prairie violet)

Method of Sowing

There have been a few changes in sowing of seed regime followed during this past decade. One of the modifications involved the use of a fertilizer buggy drawn by a tractor in order to spread uncleaned matrix seed onto prepared soil instead of using an all-terrain spreader as was previously done. Both types of machines are excellent for sowing seed, but it was more cost effective in the long run to purchase the buggy than to continually rent the all-terrain spreader each year at a time when it is in use by local farmers.

The release of the seed from the buggy is adjusted to give a maximum spread of arc and an optimum covering of the ground with seeds. This is about 27.7 kg./ha (30 lbs/acre). Afterwards a cultipacker with the tines up is usually used as a roller to ensure good seed-to-soil contact.

Since many of the matrix plants are warm season plants, sowing is usually done during the first weeks in June when the matrix seed will germinate quickly and the seedlings will grow well. However, matrix seed can be sown throughout the months of June and July and still give excellent results.

Mowing the First Year

Eurasian weeds that quickly develop in the newly seeded tracts are usually mowed once or twice during the first year or two to allow sunlight to penetrate down to the young matrix seedlings. This is accomplished using a rotary mower raised about 12 to 14 inches high. The tracts are mowed often enough so the thatch produced in the mowing does not smother the young seedlings.

ENRICHMENT OF THE PRAIRIE TRACTS

The matrix constitutes about 24% of the presettlement prairie species. However, in order to increase species diversity, it is necessary periodically to enrich the tracts with later successional species. Examples of species used include lead plant (Amorpha canescens), smooth aster (*Aster laevis*), prairie coreopsis (*Coreopsis palmata*), prairie blazing star (*Liatris pycnostachya*), purple prairie clover (*Petalostemum purpureum*), waxy meadow rue (*Thalictrum revolutum*), Culver's root (*Veronicastrum virginicum*), and golden Alexanders (*Zizia aurea*).

In addition, an effort is made to enrich the earlier plantings in which some matrix species are not well established. Species used include nodding wild onion (*Allium cernuum),* tall coreopsis *(Coreopsis tripteris*), round-headed bushclover *(Lespedeza capitata)*, yellow cone flower (*Ratibida pinnata*), and prairie dock (*Silphium terebinthinaceum*).

Collection of Seed for Prairie Enrichment

Certain species of the matrix, as well as selected species of the second stage which have large developing populations at Fermilab prairie, are collected by hand. For that purpose the Roads and Grounds Department of Fermilab organizes and supervises two seed harvest days each year using volunteers. One is in late September and the other in late October. Among the species from which seed is collected are nodding wild onion (*Allium cernuum*), prairie coreopsis (*Coreopsis palmata*), showy tick trefoil (*Desmodium canadense*), wild quinine (*Parthenium integrifolium*), and sweet black-eyed Susan (*Rudbeckia hirta*).

Seeds of later successional stages are also hand-collected throughout the year from remnant prairies within a 50-mile radius of Fermilab. One such remnant is along a railroad right-of-way running through Fermilab. Species available by this means include shooting stars (*Dodecatheon meadia*), rattlesnake master (*Eryngium yuccifolium*), button blazing star (*Liatris aspera*), prairie blazing star (*L. pycnostachya*), marsh blazing star (*L. spicata*), prairie lily (*Lilium philadelicum andinum*), and Culver's root (*Veronicastrum virginicum*).

Seed is also obtained by exchange arrangements with many of the county forest preserve districts in the vicinity of Fermilab. Matrix seed collected at Fermilab is exchanged for seed to be used in enriching the Fermi plantings.

Some of the seeds collected are relatively clean and easily separated from one another when picked, and thus they do not require further cleaning. Examples are false toadflax (Comandra *richardsiana*), shooting stars (*Dodecatheon media*), prairie clovers (*Petalostemum spp.*), and prairie cinquefoil *(Potentilla arguta*).

All seeds are held under moist conditions throughout the winter months in an unheated barn. Legumes are first scarified using blocks of wood covered with emery paper, moistened, and then inoculated with a specific *Rhizobium* culture.

Since many prairie species produce seed that remain covered within their fruit coat, a converted soil shredder is used to break up these fruits in order to release the seeds. Finally, a mechanical cleaner is used to remove dried parts of stems, leaves, and flowers that are frequently mixed in with the harvested seeds.

Methods Used in Planting Enrichment Seed Mixes

Three methods of enrichment planting are regularly used: 1) drilling; 2) mechanical broadcast sowing; and 3) hand sowing.

1) Drilling. This method involves the planting of cleaned seeds into recently burned prairie tracts by use of a Nisbet drill. Drilling of the seed into the soil offers a better chance for seed to germinate and successfully establish seedlings. This method is used to enrich the older plantings with late successional species which are relatively uncommon and difficult to collect in large quantities.

In preparation for drilling, the cleaned seeds are distributed into seven different mixtures according to the type of habitat into which they are to be planted. These habitat mixtures are: 1) mesic prairie for use in older plantings; 2) mesic prairie for use in newer plantings); 3) dry prairie; 4) wet prairie); 5) marsh; 6) savanna; and 7) woods.

Because seeds vary in size, smoothness, and sometimes fluffiness, they are placed in separate compartments of the Nesbit drill. Species with smooth seeds, such as prairie cinquefoil (*Potentilla arguta*), Culver's root (Veronicastrum virginicum), and golden Alexanders (*Zizia aurea*), are placed in the smaller compartments; whereas, species with fluffy seeds, such as prairie Indian plantain (*Cacalia plantaginea*), rough blazing star (*Liatris aspera*), and early goldenrod (*Solidago juncea*), are placed in the larger compartments. The planting rate of the seeds in each compartment can be controlled by adjusting the size of the orifice at the bottom of each compartment and the rate of flow through the drill.

The tract to be planted is first burned either in autumn or early spring to remove the dried vegetation from the previous growing season. This enables the drill to more efficiently bury the seeds into the soil. Seeds are usually planted from a quarter- to a half-inch depth.

2) Mechanical Broadcast Sowing. This method of enrichment involves the use of a fertilizer buggy pulled by a tractor. Clean or uncleaned seed is dispersed onto burned or unburned prairie tracts during the nongrowing seasons (late autumn, winter, and early spring) or onto ground covered with snow. It is generally used to enrich more recent plantings that are missing some of the species of the matrix or other early successional species.

3) Hand Sowing. This method of enrichment is especially useful to plant seed from prairie species that bloom and ripen seed in spring and early summer. This includes, false toadflax (*Comandra richardsiana*), yellow stargrass (*Hypoxis hirsuta*), hairy puccoon (*Lithospermum canescens*), pale spiked lobelia (*Lobelia spicata*), prairie lousewort (*Pedicularis canadensis*), marsh phlox (*Phlox glaberrima*), prairie phlox (*P. pilosa*), and blue-eyed grass (*Sisyrinchium albidum*). Rather than store this seed for months before planting and have it undergo loss of viability, it is hand-sown immediately after collecting into localized areas designated as **foci** (sing. **focus**) that show richer arrays of species than generally found throughout a planting, .

Fire Management

Fire is necessary for the establishment and maintenance of prairie. There is absolutely no substitute for it. At Fermilab, most of the 24 planted prairie plots have been burned repeatedly during the past 20 years either in late autumn or early spring. Prairie burns are carried out by trained crews from Fermilab's Department of Roads and Grounds.

There is no set date for burning in the autumn, but it is usually during November or early December after most seed has ripened and been harvested from the plants. Burns may be conducted until weather conditions with low temperatures and high humidity prevent a vigorous fast moving fire. Since much of the dried vegetation is standing at this time, the burns are spotty leaving the landscape with partially blackened areas interspersed with standing unburned vegetation.

In spring, burning begins when weather conditions favor fires that move aggressively though the dried prairie vegetation. Usually this period is toward the end of February or beginning of March. Burning ends before the appearance of shoots and buds of early spring prairie plants. Such plants include nodding wild onion (Allium cer*nuum*), white wild indigo (*Baptisia leucantha*), and golden Alexanders (*Zizia aurea*). Usually, the burn period ends about the middle of April. Because the winter snow flattens and compacts the dried vegetation, the spring burns are hotter and more vigorous than autumn burns. Spring burns produce a flat blackened landscape with little standing vegetation.

To facilitate burning, a group of the earliest plantings lying adjacent to each other, along with the adjoining marshes and woodlands, are designated as a single burn unit or tract. The burn unit is purposely isolated from surrounding areas by roads, creeks, and mowed fire breaks. More recently planted areas, in which the matrix species are still not well-established and dominant, are not grouped into burn units but are burned separately. A typical burn unit is approximately 200–300 acres.

The frequency with which the prairie tracts are burned varies with the age of the planting. The more recent plantings are usually burned annually for five or six years. This gives opportunity for the prairie matrix species to become established while the weedy vegetation is put under stress.

Older plantings are burned less often. Priority for burning these is given in this order: 1) tracts that have not been burned in the last two or three years and have accumulated considerable amounts of fuel load; 2) tracts that contain substantial amounts of woody vegetation; and 3) tracts that are to be enriched using a Nisbet drill.

The frequency of burning is also dependent on wind direction. There are many laboratory buildings scattered throughout Fermilab. If the smoke and ash arising from a prairie fire should blow toward any of these buildings, this could interfere with the activities within those buildings. Because of this possibility, some tracts can only be burned when wind blows from the right direction. If the proper wind conditions are not present during the burn period, a tract is not burned. For this reason certain tracts may not be burned for two or more years in a row.

RESTORATION CHRONOLOGY

In autumn the tract that has been sowed during the previous spring with prairie matrix takes on the appearance of a weedy field with an assortment of annual and first-year biennials, such as ragweeds (*Ambrosia spp.*), thistles (*Cirsium spp.*), Queen Anne's lace (*Daucus carota*), smartweeds (*Polygonum spp.*), and Eurasian clovers (*Trifolium spp.)*. However, a closer inspection of the soil surface under these weeds show young seedlings of big bluestem grass (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), showy tick trefoil (*Desmodium canadense*), wild bergamot (*Monarda fistulosa*), yellow cone flower (*Ratibida pinnata*), compass plant *(Silphium laciniatum)*, and other species of the prairie matrix. Usually after two, or possibly three, growing seasons, a sufficient fuel load has accumulated which is capable of supporting a burn.

Within five years, coupled with annual burns, the prairie matrix usually dominates a large portion of the tract. The dominant grasses are big bluestem grass (*Andropogon gerardii*) and Indian grass (*Sorghastrum nutans*). In low spots prairie cord grass (*Spartina pectinata*) slowly is becoming common. Scattered throughout the tract are the various common prairie matrix forbs, such as, nodding wild onion (*Allium cernuum*), white wild indigo (*Baptisia leucantha*), tall coreopsis (*Coreopsis tripteris)*, showy tick trefoil (*Desmodium canadense*), wild bergamot (*Monarda fistulosa*), common mountain mint (*Pycnanthemum virginianum*), yellow coneflower (*Ratibida pinnata*), black eyed Susan (*Rudbeckia hirta*), rosin weed (*Silphium integrifolium*), prairie compass plant (*S. laciniatum*), and prairie dock (*S. terebinthinaceum*).

Also present within this first stage tract are local spots with weedy vegetation representative of an earlier successional stage. Common species found in these weedy patches are Hungarian brome grass (Bromu*s inermis*), reed canary grass (*Phalaris arundinacea*), Canadian thistle (*Cirsium arvense*), bull thistle (*C. vulgare*), and tall goldenrod (*Solidago altissima*). With the passage of time and the occurrence of annual fires, these local weedy spots slowly disappear as the aggressive plants of the prairie matrix invade. These invaders include big bluestem grass (*Andropogon gerardi*), Indian grass (*Sorghastrum nutans)*, tall coreopsis (*Coreopsis tripteris*), yellow cone flower *(Ratibida pinnata*), and prairie goldenrod (*Solidago rigida*). It is interesting to observe the year-by-year disruption and contraction of swards of Hungarian brome grass (*Bromus inermis*) and reed canary grass (*Phalaris arundinacea*), and clones of tall goldenrod (*Solidago altissim*a) and Canada thistle (*Cirsium arvense*) as the matrix species invade.

During the next five to ten years Indian grass (*Sorghastrum nutans*) some of the early forbs, such as, black-eyed Susan (*Rudbeckia hirta*) and showy tick trefoil (*Desmodium canadense*), decrease in number and survive primarily on the periphery of the tract. Switch grass (*Panicum virgatu*m) is likewise relegated to a minor position and survives mostly in areas adjacent to wet areas. Both little bluestem (*Andropogon scoparius*) and prairie dropseed (*Sporobolus heterolepis*) are uncommon and local.

This leaves big bluestem (*Andropogon gerardii*) as the sole dominant grass throughout the developing prairie. The tract now has the appearance of a monoculture of this grass standing 2 m or more in height. However, throughout the tract new forbs of the prairie matrix are increasing their populations and becoming more evident, especially in foci. These forbs include: nodding wild onion (*Allium cernuu*m), wild quinine (*Parthenium integrifolium*), common mountain mint (*Pycnanthemum virginianum*), sweet black-eyed Susan (*Rudbeckia subtomentos*a), and various species of goldenrod—grass-leaved sunflower (*Solidago gymnopsermoides*), early goldenrod (*S. junce*a), gray goldenrod (*S. nemoralis*), Riddell's goldenrod (*S. riddellii*) and prairie goldenrod (*S. rigida*).

In addition to these first stage species, plant species belonging to the second stage are slowly beginning to make their appearance within foci. Examples of these species are heath aster (Aster *ericoides*), prairie sedge (*Carex bicknellii*), prairie coreopsis (*Coreopsis palmata*), shooting stars (*Dodecatheon meadia*), purple coneflower (*Echinacea pallida*), rattlesnake master (*Eryngium yuccifolium*), prairie blazing star (*Liatris pycnostachya*), marsh blazing star (*L. spicata*), pale-spiked lobelia (*Lobelia spicata*), prairie betony (*Pedicularis canadensis*), white prairie clover (*Petalostemum candidum*), and purple prairie clover (*P. purpureum*), marsh phlox (*Phlox glaberrima interio*r), false dragonhead (*Physostegia virginiana)*, and Culver's root (*Veronicastrum virginicum*).

From the tenth and to the fifteenth years, Stage 2 species within foci slowly increase their numbers. Isolated specimens of new species of the second stage begin to appear for the first time. These include Indian plantain (*Cacalia tuberosa*), water hemlock (*Cicuta maculata*), Illinois tick trefoil (*Desmodium illinoense*), bottle gentian (*Gentiana andrewsii*), yellow gentian *(G. flavida*), cardinal flower (*Lobelia cardinalis*), cowbane (*Oxypolis rigidior*), prairie parsley (*Polytaenia nuttallii*), and glaucous white lettuce (*Prenanthes racemosa*).

Between the fifteenth and twentieth years Stage 2 species increase in numbers and begin to increase the size of the foci. New populations of these and other second stage species slowly begin to appear throughout the tract. The additional species of Stage 2 are (prairie coreopsis (Coreo*psis palmata*), shooting stars (*Dodecatheon media*), purple coneflower (*Echinacea pallida*), rattlesnake master (*Eryngium yuccifolium*), northern bedstraw (*Galium boreale*), prairie blazing star (*Liatris pycnostachya*), marsh blazing star (*L. spicata*), prairie lousewort (*Pedicularis canadensis*), marsh lousewort (*P. lanceolata*), marsh phlox (*Phlox glaberrima interior*), false dragonhead (*Physostegia virginiana*), blue eyed-grass (*Sisyrinchium albidum*), and Culver's root (*Veronicastrum virginicum*).

During this time, species of the third stage also begin to appear in the developing prairie. These include little bluestem grass (Andro*pogon scoparius*), smooth blue aster (*Aster laevis*), narrow-leaved loosestrife (*Lysimachia quadriflora*), and great plains ladies' tresses (*Spiranthes magnicamporum*).

Succession and Soils

The time needed for the prairie matrix to suppress the weedy vegetation and become dominant is relatively rapid, usually occurring within three to five years. Vagaries of the weather, such as droughts, following the sprouting of seedlings, can extend this time. Even under relatively favorable weather conditions, the dominance of species of the second stage occurs very slowly. This slow pace may, in part, be due to degraded soils.

The soils on which the Fermilab prairie are being restored have been in cultivation for more than 150 years. It is probable that these soils during agricultural use may have undergone certain physical and biological changes, making these soils different from those originally present in presettlement times. Thus, the second and the later stage species do not initially find soil conditions favorable for growth in competition with species of Stage 1.

The presence of physical conditions conducive to vigorous microbiological activity and associated good plant growth in most soils depends upon the binding of soil particles into stable aggregates of various sizes. These provide a range of pore sizes for storage of plant-available water, transmission of water and air, and root growth (Harris et al. 1966, Oades 1984). Cultivation of virgin grassland soils results in a significant loss of water-stable aggregates and often changes the distribution of aggregate size classes (Low 1972, Dormaar 1983, Cook et al. 1988, Jastrow 1987, Miller and Jastrow 1990). It is probable that many prairie species require these water-stable aggregates for their successful entry and establishment in restoration prairies. Prairie gentian (Gentiana puber*ulenta*), which grow from tiny and slow-growing seedlings during their first year, may be an example of a species that requires these water-stable aggregates for their development.

It is also probable that the cultivation and resultant destruction of the prairie flora also caused the extermination of the micro-flora (mycorrhizal fungi, bacteria, and protozoa) characteristic of the virgin prairie soil. Without these symbiotic organisms many prairie plants, such as eastern prairie fringed orchids (Haben*aria leucophaea*) with their mycorrhizal fungi and various prairie legumes (*Amorpha, Baptisia, Lespedeza, Petalostemum*) with their associated bacteria (*Rhizobium spp*), are less competitive within a prairie ecosystem (Dhillion and Friese 1994).

The richer array of Stage1 species and the usual first appearance of Stage 2 species in foci may be due in part to the higher number of water-stable aggregates and richer soil micro-flora than are generally found throughout the matrix.

Support for this hypothesis is shown by the relatively rapid invasion of later successional species into previously cultivated agricultural land from adjacent virgin or near virgin prairie. This has been observed along a railroad prairie at Fermilab.

This same rapid establishment of second stage species into formerly cultivated land has been observed at Gensburg-Markham Prairie, Markham, Illinois. In 1972 this 40.5 ha (100 a) prairie was acquired by Northeastern Illinois University. This prairie consisted of approximately 28.3 ha (70 a) of virgin prairie next to an adjacent 12.1 ha (30 a) naturally restored prairie. This restored prairie had developed on agricultural land removed from cultivation in 1925, and thus there was a period of some 47 years available for its re-establishment. The restored prairie was dominated by three prairie grasses, big bluestem (*Andropogon gerardia*), little bluestem (*A. scoparius*), and Indian grass (*Sorghastrum nutans)* with few second stage plants (Hanson 1975, Post 1980). In the late 1970s efforts were made to further restore this degraded prairie by hand-sowing second- and third-stage species into it. Within a few years populations of these species, including prairie coreopsis (*Coreopsis palmata*), purple and white prairie clovers (*Petalostemum* spp.), and prairie and marsh phloxes (*Phlox* spp.) were able to establish themselves within the degraded prairie.

A similar phenomenon was observed in the restoration of cemetery prairies in Illinois and Indiana (Betz and Lamp 1989). On first observance, a large portion of these cemeteries had been mowed for decades and gave little evidence that they still contained prairie plants. However, around the tombstones and fences there were isolated clumps of big bluestem grass (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), lead plant (*Amorpha canescens*), prairie dock (*Silphium terebinthinaceum*), and compass plant (*S. laciniatum*). Close inspection of the mowed blue grass lawn (*Poa pratense*) with its complement of dandelions (*Taraxacum officinale*) showed widely scattered tiny depauperate prairie plants (dubbed "bonsai plants"), such as purple prairie clover (*Petalostemum purpureum*), prairie gentian (*Gentiana puberulenta*), and heart-leaved golden Alexanders (*Zizia aptera*). When mowing was discontinued, these widely scattered bonsai plants began to recover.

Two years after cessation of mowing, these overgrown bluegrass lawns with the rare nonblooming depauperate plants were burned in the spring. In the following two summers, the cemetery took on the aspect of a matrix prairie with tall bluestem grass (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), wild bergamot (*Monarda fistulosa*), yellow coneflower *Ratibida pinnata*), stiff golden rod (*Solidago rigida*), and compass plant (*Silphium laciniatum*).

Within four or five years after the initial burn, the isolated prairie plants of the second and third stages such as, purple and white prairie clovers, lead plant, prairie gentians, hoary puccoon (Lith*ospermum canescens*), and prairie phlox (*Phlox pilosa*) were quickly replacing plants of the prairie matrix. After a decade of recovery, these cemetery prairies resembled virgin prairies with little or no traces of a bluegrass lawn that may have covered them for decades.

In order to speed the entry of the prairie soil micro-flora into degraded prairie soils, it might be necessary to remove a limited number of plugs of soil from the edges of virgin or near-virgin prairies for use in inoculating **foci** within a tract being restored.

It also could be accomplished by first growing plants of the second and third stages in pots with their mycorhizal fungi and then transplanting into the matrix prairie. It might also be done by digging these plants from prairie remnants that are to be destroyed. However, it is difficult to transplant prairie plants into an established prairie since wild animals have a tendency to dig up the plants as soon as they are planted. Very few transplanted prairie plants ever survived their depredations.

Weeds within the Prairie Matrix

When burned annually, the prairie matrix is very competitive against most agricultural weeds, such as ragweeds (*Ambrosia*), mustards (*Brassica*), lamb's quarters (*Chenopodium*), pepper-grasses (*Lepedium*), medicks (*Medicago*), plantains (*Plantago*), smartweeds (*Polygonum*), docks (*Rumex*), foxtail grasses (*Setaria*), clovers (*Trifolium*), and speedwells (*Veronica*). Various thistles, such as nodding thistle (*Carduus nutans*), bull thistle (*Cirsium vulgare*), and even the rhizomatous Canadian thistle (*C. arvense*) will quickly disappear from annually burned tracts.

However, the biennial white sweet clover (Meli*lotus alba*) is able to co-exist within the annually burned developing prairie matrix. This Eurasian exotic acts as though it is a true native prairie plant in that it thrives under a prairie fire regime. Regardless of what is reported in the literature, it appears that the time of burning (early autumn, late spring, etc.) has little bearing on its disappearance from the developing prairie. If the prairie is not burned for a few years, this weed maintains a very low profile with only a few plants here and there throughout the tract. However, after the first burn, the plant is back in great abundance. Observations at the Gensburg-Markham Prairie, where the prairie has been burned almost annually for the past 25 years, indicate that over time as the diversity of prairie species increases, white sweet clover decreases in abundance. The periods between flareups of this plant lengthen, and finally the plant disappears within the prairie tract. This phenomenon has also been observed in virgin old settler cemetery prairies (Betz and Lamp 1989). However, all that is needed is for a woodchuck or ground squirrel to disturb the ground and a few white sweet clover plants will find their way back into the area to start the process all over again, at least for a year or two.

Big bluestem grass (*Andropogon gerardii*) and Indian grass (*Sorhastrum nutans*) of the prairie matrix will both slowly eliminate Hungarian brome grass (*Bromus inermis*) and quack grass (*Agropyron repens*) from a developing prairie if the tract is burned annually.

Depending on the water table, reed canary grass (*Phalaris arundinacea*) is slowly outcompeted by both big bluestem grass (*Andropogon gerardii*) on the mesic sites, and prairie cord grass (*Spartina pectinata*) and rhizomatous sedges, such as broad-leaved woolly sedge (*Carex pellita*), on the wetter sites. First indications of its weakening is a reduction in height and the vigor of flowering. Annual burning of the prairie is an absolute necessity in order to achieve a slow elimination of reed canary grass. If the developing prairie is not burned, reed canary grass will outcompete the prairie grasses and take over an area.

WET MEADOWS

Wet meadows are widely scattered throughout Fermilab. Most of these are only a few acres in extent, but there are some of ten or more acres. They are usually wet in spring with a few inches of standing water. They are dry during summer except for a few days following a heavy rain storm.

While some of these were present prior to presettlement days, others have been recently formed as a result of the construction of Fermilab. Originally, most of Fermilab was agricultural land which was heavily crisscrossed with drain tiles. Thus, when the accelerator ring was built, these tiles were broken and wet meadows began to form in low spots within the ring. A similar situation exists outside of the accelerator ring.

Wet Meadow Succession

In contrast to prairie vegetation which was almost destroyed by agricultural cultivation during the past 150 years or more, some of the wet meadow vegetation has survived in a few small isolated wet pockets that were not cultivated. With the cessation of cultivation in the late 1960s, these degraded marsh remnants began to recover and even spread into new wetlands that were coming into being by the destruction of the drain tiles.

These wet meadows are slowly moving through successional stages. The stages that have been observed include successively: (1) weedy annual stage with clammy hedge hyssop (*Gratiola neglecta*) and false pimpernel (*Lindernia dubia*); (2) an intermediate stage with sedges (*Cyperus* spp.), spike rushes (*Eleocharis* sp.), rushes (*Juncus* spp.), common water horehound (*Lycopus americanus*), caespitose carices (*Carex cristatella, C. stipata, C. scoparia, and C. vulpinoidea),* monkey flower (*Mimulus ringens*), water heartsease (*Polygonum coccineum*), water knotweed (*P. amphibicum stipulaceum*), and various rushes *(Scirpus acutus*), (*C. atrovirens*) (*S. fluviatilis*) (*S. lineatus*) and) (*S. vallidus*); and (3) a prairie cord grass stage, showing an increasing prevalence of prairie cord grass (*Spartina pectinata*), blue joint grass (*Calamagrostis canadensis*), and various rhizomatous sedges (*Carex atherodes* and *C. pellita).*

Wet Meadow Enrichment

Over the past two decades efforts have been made to enrich these wet meadows with seed collected on site or obtained by trading seed from local county forest preserve districts. Since planting cannot be done by mechanical sowing or drilling because of the wet ground, seeds are usually hand-sown during the winter months when the ground is frozen over and even covered with snow. This enables the seed to be more evenly distributed throughout the wet meadow. As the snow and ice melt, the seeds fall to the wet soil.

SAVANNA/WOODLANDS

There are approximately a dozen farm woodlots scattered throughout the western part of Fermilab. These are remnants of the once extensive presettlement savanna listed in the first surveyor's notes as the "Big Woods." The dominant tree is bur oak (*Quercus macrocarpa*) along with red oak (*Q. rubra*) and white oak (*Q. alba*). Other trees present in these woods are sugar maple (*Acer saccharum*), shagbark hickory *(Carya ovata),* bitternut hickory (*C. cordiformis*), white ash (*Fraxinus americana*), black ash (*F. nigra*), and basswood (*Tilia americana*).

Like most Midwest woodlots, all have had a history of being grazed by farm animals. Only two of the Fermilab woodlots have retained a good representation of the presettlement ground flora. The remainder have been severely degraded by overgrazing.

Woodland Enrichment

The size of the savanna and woods on site are regularly being enlarged by transplanting young bur oak (Que*rcus macrocarpa*) and shagbark hickory (*Carya ovata*) saplings from high density thickets to open fields adjacent to woodlands by use of a mechanical tree spade. Planting is done in such a way as to eliminate the straight fence lines of trees and shrubs that are reminders of a previous agricultural era.

Also, over the past decade efforts have been made to enrich the ground cover of these woodlots either by hand-sowing seed throughout the year or broadcasting seed using a fertilizer buggy. Some of the seed is hand-collected from richer woods on site. Species thus planted include wood mint (*Blephilia hirsuta*), Dutchman's breeches (*Dicentra cucullaria*), sharp-lobed hepatica (*Hepatica acutiloba*), golden seal (*Hydrastis canadensis*), and American gromwell (*Lithospermum latifolium*). Other woodland seed is obtained from neighboring county forest preserve districts by trading prairie matrix seed for woodland seed. This includes wild columbine (*Aquilegia canadensis*), poke milkweed (*Asclepias exaltata*), and ginseng (*Panax quinquefolius*).

Wooded Swamps

There are a few wooded swamps along Indian Creek, a tributary of the Fox River, which drains the southern portion of Fermilab. The dominant tree along this water course is swamp white oak (Quercu*s bicolo*r). The locally rare kingnut hickory (*Carya laciniosa*) is also found there. Some of the swamp plants found are swamp sedge (*Carex muskingumensis*), hop sedge (*C. lupulina*), common wood reed (*Cinna arundinacea*), sweet-scented bedstraw (*Galium triflorum*), and button bush (*Cepahlanthus occidentalis*).

The diversity of species within these swamps is being increased by collecting seed on site for dispersing along Indian Creek.

Effect of Animals on Prairie Restoration

Because of its size (approximately 7000 acres) and diversity of plant communities, many animals species have gravitated to Fermilab. Among the mammals recorded at Fermilab are: white-tailed deer, coyotes, minks, weasels, voles, beavers, red foxes, raccoons, badgers, woodchucks, and opossums. Among the birds there are seven or more pairs of breeding red-tailed hawks, horned owls, short-eared owls in winter, a colony of blue heron, American egrets, upland sandpipers, meadow larks, bobolinks, marsh wrens and rails. During migration a variety of warblers and waterfowl are found in the woods and marshes, including flocks of sandhill cranes. As the prairie develops, there is an ever-increasing diversity of insects, including butterflies, native bees, and flies.

Most of these animal species cause very little damage or problems. However, the white-tail deer are causing serious problems in the restoration of both prairie and woodland at Fermilab. Without any population control this animal has reached epidemic proportions during the last two decades. They feed principally on the flowers of a wide variety of both prairie and woodland species, preventing them from setting seed. Among the woodland species that they are especially fond of are trilliums, Jack-in-the-pulpits, and woodland phlox in the wooded areas. On the prairie tracts being restored they are fond of consuming the flowers of lilies, phloxes, showy-tick trefoils, wild indigos, and shooting stars. Interestingly, they do not seem to like the flowers of the Compositae, such as the goldenrods, asters, coneflowers, and the silphiums. Studies are under way to control their population.

CONCLUSIONS

The changes in the methods of planting and enrichment of the prairie being restored at Fermilab during the past two decades may help others who are interested in large scale prairie restoration.

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ECOLOGICAL CLASSIFICATION SYSTEM DEVELOPMENT AND USE IN MINNESOTA STATE PARKS

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ABSTRACT: The State of Minnesota is developing an Ecological Classification System at the Province, Section, Subsection, Landtype Association, Ecological Landtype Association, and Ecological Landtype Phase levels. Classifications being completed on a statewide basis are the Province, Section and Subsection levels at the current time. The Department of Natural Resources, Division of Parks and Recreation, has undertaken work on the Ecological Landtype Phase level in two state parks: Banning (6000 acres) and Savanna Portage (16,000 acres). The ECS was completed at Banning in 1992 and is being used as a test model. The ECS at Savanna Portage was started this year (1996) and will be used to set the criteria for future work. The ECS's will be used as guidelines for vegetation management, in park development analysis, and as part of the ecosystem based management process.

Key words: Ecological Classification System, vegetation management, Ecological Landtype Phase, state parks, ecological key

INTRODUCTION

The state of Minnesota began to develop a statewide Ecological Classification System (ECS) in the early 1990s. Three Provinces (Bailey and Cushwa 1981) were designated which reflect differences in climate, latitude, continental landmass, soil formation, and vegetative life forms of Minnesota. These provinces are the 1) the Laurentian Mixed Forest in the north and northeast 2) the Eastern Broadleaf Forest in the southeast and central, and 3) the Prairie Parkland in the west and southwest.

The provinces were then divided into sections based on the following criteria: precipitation and temperature regimes, relief, geomorphic process and geologic age/origin, order, suborders, or great groups of soils, and formation or series of plants. The Laurentian Mixed Forest Province contains 5 sections: 1) the Northern Superior Uplands, 2) the Northern Minnesota and Ontario Peatlands, 3) the Minnesota Drift and Lake Plains, 4) the Southern Superior Uplands, and 5) the Western Superior Uplands. The Eastern Broadleaf Forest Province contains 3 sections: 1) the Lake Agassiz Aspen Parklands, 2) the Minnesota and Northeast Iowa Morainal, and 3) the Driftless and Dissected Plateau. The Prairie Parkland Province contains 2 sections: 1) the Red River Valley and 2) the North Central Glaciated Plains.

At the next level, work is currently being completed on 24 subsections (Hargrave 1994): 12 in the Laurentian Province, 8 in the East Broadleaf, and 4 in the Prairie Province. The landtype association work will begin at a later date followed by the Ecological Landtype Association. There is, however, a demonstrated need for the Ecological Landtype Phase delineation at the land management level. The current inventory information is dated in many of the state parks. This information does not provide us with the current status of the natural resources in these areas. The Ecological Landtype Phase will fill in those gaps.

Banning State Park

In 1992, a Geographic Information System (GIS) was being developed for Banning State Park located in Pine County on the Kettle River (a State Scenic River). This was in response to a need to provide information for trail development, a project for the removal of a 1906 hydroelectric dam on the river, and an adequate sewage disposal system for the campground.

Information that was available for the data layers included the following: surficial and bedrock geology at a scale of 1:250,000, (Morey 1976, Morey, Sims 1970a) soil survey for Pine County (Simmons and Shearin 1935), Department of Natural Resources (DNR) forestry vegetation data (1978), surface hydrology, bedrock hydrology, and manmade features (roads, trails, and buildings).

When mapped, the soil information was found to be one-fourth of a mile off between the section line and the river. The river had not changed course as it was carved through bedrock. This meant the soil information was useless for the intended purposes. The vegetation information was 15 years old and did not contain any information about the ground story nor the listed species. This level of detail was not acceptable. The discussion then centered on the gathering of current acceptable information. The first option was to conduct a separate soil and vegetation survey. Both would be costly, would cover the same area, and would still require analysis.

The Chippewa National Forest was developing an Ecological Landtype Phase classification in cooperation with the DNR County Biological Survey and DNR Forestry division. They made a proposal to develop a classification system for Banning State Park. The cost was $9000 for 6000 acres. An added cost was a stereo CIR (color infrared) flight at 1:4800 (13 inches per mile) which would have been flown for either process. The ECS project was accepted as a pilot for the DNR.

Nine landtypes (Almendinger 1991) were identified within Banning State Park. These were broken down into six subclassifications based on degree of slope (Table 1). This information has also been digitized into a GIS ARCINFO polygon layer from the 1:4800 aerial photographs. This provides the location of each defined classification unit. These units were mapped as polygons ranging in size from 249 m^2 (.06 acre) to 1,147,156 m^2 (283 acres).

The information on the landtypes was provided in a publication (Gallagher and Shadis 1992) containing a key (Table 2), legend descriptions, and photographic examples. A typical landtype legend description contained the following information (Table 3).

Use in Banning State Park

The Ecological Landtype Phase has been used in a number of assessments. One characteristic stood out above the rest—the water regime indicated that the entire area of the park and the sandstone substrate was either 1) a ground discharge into the Kettle River, 2) a collector/transporter, or 3) a groundwater recharge area. The bedrock geology mapping indicated the bedrock to be the Simon-Hinckley formation. This formation is at or near the surface in the park, hence, it is a groundwater recharge area for the Simon-Hinckley Aquifer that is the deepest aquifer for the Twin Cities. This is of particular importance when assessing any project that may have a direct impact on the groundwater in regard to the Simon-Hinckley formation and the Kettle River.

Kettle River Dam Removal and Floodplain Restoration

The removal of the 1906 hydroelectric dam was one of the first projects for which the ECS was used. The primary use was for information on the plant and animal communities

Table 1. National hierarchical framework - ecological units for ecosystem classification.

	Climate	Geology & Topography	Soil	Vegetation
Province	Climatic zones, precipitation, and temperature	Latitude and continental landmasses	Broad areas of similar climatic influence on soil formation	Broad areas of similar climatic influence on vegetative life forms
Section	Precipitation and temperature	Bedrock features Surficial geology Elevation	Types of glacial sediment	Distribution of plant communities
Subsection	Precipitation and temperature	Surficial geology Elevation	Phases of orders, suborders, or great groups	Vegetation at time of public land survey
Landtype Association	Precipitation and temperature	Glacial landforms Depth to bedrock Bedrock type Topographic roughness	Soil parent material Regional hydrology	Vegetation at time of public land survey Current landuse
Ecological Landtype Association	Precipitation and temperature	Topographic roughness	Soil types Hydrology	Historic vegetation disturbance regimes Abundance and distribution of wetlands
Ecological Landtype Phase	Precipitation and temperature	Landscape position	Water chemistry Soil texture Soil drainage	Plant communities Indicator plants

Table 2. Ecological Landtype phase key for Banning State Park.

Classification	Landtype	Slope
A-3	Dry Red Pine/Wintergreen/Feathermoss Excessively drained, exposed bedrock	6-12%
A-4	Dry Red Pine/Wintergreen/Feathermoss Excessively drained, exposed bedrock	12-18%
A-5	Dry Red Pine/Wintergreen/Feathermoss Excessively drained, exposed bedrock	18-35%
A-6	Dry Red Pine/Wintergreen/Feathermoss Excessively drained, exposed bedrock	35+%
B-2	Dry Hardwoods Well drained, shallow, rocky loams	2-6%
B-3	Dry Hardwoods Well drained, shallow, rocky loams	6-12%
B-4	Dry Hardwoods Well drained, shallow, rocky loams	12-18%
B-5	Dry Hardwoods Well drained, shallow, rocky loams	18-35%
C-1	Mesic Hardwoods, Pagoda-Dogwood, Partridgeberry Moderately well drained loams	0-2%
C-2	Mesic Hardwoods, Pagoda-Dogwood, Partridgeberry Moderately well drained loams	2-6%
C-3	Mesic Hardwoods, Pagoda-Dogwood, Partridgeberry Moderately well drained loams	6-12%
D-1	Wet-Mesic Quaking Aspen, Lateral-flowered Aster Somewhat poorly drained loams	0-2%
E-1	Wet Black Ash, Cinnamon Fern, Brome Sedge Poorly drained, shallow muck	0-2%
F-2	Dry Pine - Hardwood forest Somewhat excessively drained sandy soil	2-6%
F-3	Dry Pine - Hardwood forest Somewhat excessively drained sandy soil	6-12%
G-2	Mesic to wet Silver Maple, Wild Grape, Wood Nettle Somewhat poorly to well drained alluvial soils	2-6%
H-1	Wet *Carex lacustris*, *Carex stricta* Very poorly drained Sedge Peat	0-2%
I-1	Wet Labrador Tea, Leather Leaf, Sphagnum Very poorly drained Sphagnum Peat	0-2%
Alluvium	Conifer forest Rocky alluvial soils	None

Table 3. Elements of an Ecological Landtype Phase Legend Description

1.	Habitat	10.	Characteristic plant species
2.	Landform	11.	Soils
3.	Landscape position	12.	Water regime
4.	Substrate	13.	Disturbance regime
5.	Vegetation structure	14.	Successional status
6.	Common tree species	15.	Commonly associated landtypes
7.	Common shrub species	16.	Threats
8.	Common forb species	17.	Management highlights
9.	Common graminoid species	18.	Rare plant and animal species

that might be restored in the area once the pool was drained. Some indication came from the communities already adjacent to the existing pool. The community on the west side of the pool was mesic to wet silver maple, wild grape and wood nettle with somewhat poorly to well-drained alluvial soils and a slope of 2-6%. The east side of the pool was covered by a dry red pine, wintergreen and feather moss community. The substrate was excessively drained, exposed bedrock with a slope of 18-35%. This was also the case on the west shore as the vegetation progressed away from the river.

Once the dam was removed, the exposed pool bed would fit into the vegetation community on the west side of the river. This was shown by the existing contour map of the pool. The soil was alluvium in the floodplain, subject to periodic flooding, and was affected by numerous seeps adjacent to the floodplain. The vegetation key indicated silver maple, cottonwood, and green ash were the main species to be used for this community restoration. The areas remaining above the floodplain were to be planted to trembling aspen, paper birch, and red maple because this would be an alluvial terrace as identified by the ecological landtype phase key.

Power Line Maintenance

A second project was initiated by Minnesota Power and Light which provides electrical services to the park. To maintain service, they periodically spray herbicide under the power lines. Based on the results of the ECS, DNR discussed concerns about the park's sensitivity to artificial chemicals with Minnesota Power. As a result of the meeting, the proposed spray area was reduced by 50%. After Minnesota Power had the opportunity to review the ECS, they offered to spray only 33% of the originally proposal area. This decision meant that the park's resources were impacted less than originally anticipated and the power company saved on expenses and labor. Minnesota Power has since expressed an interest in having this information for other parks to which they provide service.

Sewage Lagoon Project

Banning State Park has had a history of sewage disposal problems ranging from failed drain fields to blown out mound systems. The current project will replace these with a lagoon system. At this time, the park's resources are being assessed to determine the feasibility of this project. The ECS will provide information along with an engineering analysis to access the workability of this project. As personnel become more familiar with the ECS system, its use is expected to increase for all types of projects, including natural resource management.

CONCLUSIONS

In 1996, the Minnesota County Biological Survey began a pilot project at Savanna Portage State Park to develop statewide data collection criteria for the ecological landtype phase. Savanna Portage lies in both the St. Louis Moraines and Tamarack Lowlands subsections and contains characteristic land types that can be analyzed to develop criteria for uplands, lowlands, and wetlands.

Ecological Landtype Phase development also began at St. Croix State Park in 1996. This park is in the Mille Lacs Uplands and is the largest in the Minnesota State Park system with an area of 34,000 acres.

The Ecological Landtype Phase development began at Mille Lacs Kathio State Park (10,000 acres) in 1998. Completion is expected by the year 2000.

The coverages for these three parks will be used primarily for natural resources management and other, yet to be identified, projects.

Ecological Classification System information is expected to be valuable in many ways, not only for the DNR Division of Parks and Receration, but for the management of natural resources by many agencies of the state of Minnesota.

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THE BIOSPHERE RESERVE PROGRAM IN AUSTRALIA: LANDSCAPE MODELS FOR SUSTAINABLE CONSERVATION AND RESOURCE USE

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ABSTRACT: The international network of biosphere reserves was originally implemented by the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) Man and Biosphere (MAB) biosphere reserve program to protect the world's major biomes or ecological units. Its mission now focuses on the need to reconcile the utilization of natural resources with long-term protection of biodiversity through an interdisciplinary approach to sustaining nature and society. This is the essence of what we now call "ecologically sustainable development." An overview of the functions, concepts, and misconceptions of biosphere reserves is given.

One state-of-the-art model being developed by local communities in the Riverland in South Australia is Bookmark Biosphere Reserve. It draws together community visions, values, and actions dealing with a complex web of environmental and social challenges through a similarly complex network of multiple land tenures, public-private partnerships and resources, and multi-disciplinary professional capacities. Of note is the considerable support this project has been given through the Chicago Zoological Society.

The need to implement and experiment with innovative approaches to sustainability is now more critical than ever. The Biosphere Reserve Program is maturing through better integration of cultural needs and aspirations for quality of life while conserving natural values and ecosystem processes. I wish to encourage more models like the Bookmark experiment to evolve through even greater creativity and engagement with public and private partners.

Key words: UNESCO, Biosphere Reserve, sustainable development, restorative industries.

INTRODUCTION

Ultimately, an adequate conservation strategy depends on a variety of successful policies applied effectively outside reserves to ensure protection of landscape- and seascape-scale ecological functions, habitat restoration, and ecologically sustainable use. Preserved natural areas and other reserves or protected areas are a necessary, but not sufficient condition, for long-term sustainability. Even a comprehensive protected areas system is not a panacea for sustaining ecological diversity—most biodiversity will always be found outside the reserve system. Therefore, networks of protected areas must also be managed in concert with entire regions (Noss 1983; HoRSCERA 1992, 1993; Brunckhorst and Bridgewater 1994, 1995). Protected areas should also function as reference sites—essentially, measuring sticks for landscape wide conservation and sustainability objectives. They are, or should be, of value to local people who share responsibility for conservation across the landscape, both within and outside protected areas (Saunders 1990, IUCN 1993).

As society struggles to come to grips with increasing degradation of the land, its resources, and faltering ecosystems, all governments are realizing their limited resources and professional capacities, to assist social change towards a sustainable future. The Landcare movement in Australia has also contributed to public debate of the appropriate responses of government. Increasingly, authorities from a variety of disciplines (economics, social sciences, biological sciences etc) are also recognizing the limited capacities of traditional forms of public sector organization to deal effectively with the scale, complexity, and inter-relatedness of environmental problems for long-term sustainability. This recognition challenges the ability of compartmentalized government bureaucracies to adjust to, or engage in more integrated on-ground models.

Australia's strategy for Ecologically Sustainable Development (ESD) (agreed upon by all governments in 1992) recognizes that partnerships between government and communities at all levels are vital in the quest for integrated sustainable development and conservation. The Australian Nature Conservation Agency is attempting to meet this challenge through a landscape view of the world which moves its functional units beyond a traditional narrow focus for program delivery. Institutional evolution towards a culture that can encourage and partake of integrated models requires a new definition of management—replacing the idea of control by a few people with that of negotiation and organizational learning. Hence, land and sea management is teamwork (by partners) based on a continually evolving consensus on the direction towards sustainable development.

This is the background of science and policy that has now catalyzed a resurgence of interest in further development, use and demonstration of landscape ecology (Hansen and DiCastri 1992, Noss 1983, Slocombe 1993, Brunckhorst 1998), bioregional approaches (HoRSCERA 1992,1993; Brunckhorst 1995), and the UNESCO Biosphere Reserve Program (UNESCO 1995; Brunckhorst and Bridgewater 1994, 1995). Such approaches, coupled with the biosphere reserve program, offer opportunities for diverse and innovative responses because they are: set in the context of landscape- (or regional-) scale ecological processes; trans-disciplinary;,cross-sectoral and cross-jurisdictional; built on multiple public-private capacities; and can be owned and driven by local communities.

> Biosphere reserves offer such models. Rather than forming islands in a world increasingly affected by severe human impacts, they can become theatres for reconciling people and nature. They can bring knowledge of the past to the needs of the future and they can demonstrate how to overcome the problems of the sectoral nature of our institutions. (Vision from Seville," UNESCO 1995, p. 4)

The seminal meeting for what would become the Man and the Biosphere (MAB) biosphere reserve program was held at UNESCO House in Paris in 1968. The Biosphere Reserve program began in earnest with the first meeting of the MAB International Coordinating Council in 1971.

The international network of biosphere reserves was proposed to protect the world's major biomes or ecological units. By the time the Minsk Action Plan for Biosphere Reserves (UNESCO 1984) was produced, the program was already visionary; aiming to reconcile utilization of natural resources with long-term protection through an interdisciplinary approach to sustaining nature and society (Batisse 1982, 1993; UNESCO 1984, 1995). Over 200 biosphere reserves had been nominated by 1984. There are now 330 biosphere reserves in 125 participating nations. The international network also provided a unique set of sites and opportunities for long-term monitoring, research, and communication into the ecological, social, and economic aspects of conservation and sustainable development.

Biosphere Reserve Principles

"Biosphere'"refers to that part of the earth supporting life. The long-term existence of human society on earth depends on the value we put on environmental sustenance today, for tomorrow. The biosphere provides our living space and our economy.

Scale is a critical attribute (see Norton and Ulanowicz 1992, Slocombe 1993). The landscape scale is the main scale of human interaction with the environment. The landscape-regional context links multiple spatial and temporal scales of biodiversity with human uses and socio-economic imperatives. Human systems for environmental management, however, tend to be more narrowly focused.

Biosphere reserves are fundamentally concerned with whole of landscape processes, whether inside or outside of protected areas, across a variety of land tenures and uses. They aim to sustain the biodiversity and productive capacity on a regional scale that is appropriate to the ecological processes and human use and cultural identity with that landscape. Hence, they are vehicles for managing the social, cultural, and institutional change and capacity building which are required to deal with the future sustenance of the biosphere and humanity.

The MAB program provides an enabling mechanism and multiple tools to explore new methods for planning and practicing sustainable resource management integrated with conservation activities. A biosphere reserve gives local communities new responsibilities for their own sustainable future while providing a thread to re-sew peoples identity to the landscape. This contrasts with a people managing its own "patch" in isolation and/or being excluded from ownership and responsibility for managing nearby public land in a wider context. The functions of biosphere reserves are implemented across a landscape of different uses and environmental conditions.

Major functions of the UNESCO Biosphere Reserve Program were traditionally described as conservation, development, and logistic support (research, monitoring, education and training). These functions might now be elaborated as:

- conservation of biodiversity;
- increased ecological understanding (at regional landscape scales) and,
- experimentation with, and demonstration of, ecologically sustainable development.

These are integrated through a multi-disciplined approach, focusing on the following ten objectives:

1. local community participation,
2. integrated land use management,
3. *in situ* conservation and restoration,
4. research,
5. monitoring,
6. regional planning and development,
7. environmental education and training,
8. ecologically sustainable development,
9. information and communication, and
10. developing an international network.

In the 1984 Action Plan, these functions became generalized for practical implementation and planning as "core," "buffer," and "transition" zones (UNESCO 1984, Parker 1993, Bridgewater 1994). While generally portrayed as a circular "target" diagram, the concept refers to the need to circular "target" diagram, the concept refers to the need to manage land uses and functional ecological flows across an entire landscape mosaic including a socio-economic dimension. The "core" areas are priority conservation areas representing regional biodiversity and as monitoring or reference sites for adaptive management. Buffer zones are one end of a continuous transition region extending further into an area of cooperation where biodiversity-threatening influences on the core and surrounding landscape are minimized (Batisse 1982, 1993; Brunckhorst and Bridgewater 1994, 1995). In addition, biosphere reserves provide increased community ownership and responsibility of protected areas as well as private lands, environmental restoration, monitoring, and experimental ESD projects with public and private partners. A fourth zone might therefore be termed a Zone of Cooperation. The Zone of Cooperation may occur within or as part of the transition zone or extend well beyond the transition zone—perhaps as a network with local communities and towns. In the case of the Bookmark Biosphere bioregional project, described here, seven towns within the broader region are involved in the project. It includes coordinated management of public land through a community trust. In addition, several private landholders have requested affiliation with the project or donated their land (without loss of their private title) as buffer/transition zone components of the nominated UNESCO Biosphere Reserve.

Biosphere reserves have been compatible with (and even an operational framework for) the philosophy of sustainable development, well before this concept was promoted through the Brundtland Report (World Commission on Environment and Development [WCED] 1987) and more recently through Australia's ESD Strategy (1992).

People are an essential part of the fabric of landscapes. There is probably no ecosystem which remains unaffected in some way by human activity. People and their activities are considered a part of a biosphere reserve and they should be encouraged to participate the program at a local level to gain a feeling of ownership in it. This not only encourages greater acceptance and understanding of the need to conserve biodiversity but ensures the operation of the biosphere reserve as an agent of social transformation of attitudes and values toward a sustainable future (Brunckhorst 1998).

Sustaining biological diversity will not be achieved in highly protected reserves, nor even along their boundaries. The debate is no longer based on viewing conservation reserves (large or small) from their borders inwards but is now focused outwards from the borders and on whether the borders should exist at all. Conservation reserves will still be important, but must become "open" reserves in the context of the broader landscape. By engaging local communities with experimentation and demonstraion of sustainable development and conservation, they will be able to sustain biodiversity both within their borders and in the environment beyond. The core-buffer-transition concept might be better envisaged as ripples on a pond—conservation as an open system—spreading out across a landscape building a sustainable future for people and maintaining ecological functions.

But what policy and practical mechanisms will allow a more integrated cross-jurisdictional mechanism for planning sustainable land use? Biosphere reserves represent a local level of bioregional planning (Noss 1993; Brunckhorst and Bridgewater 1994, 1995; Reid and Murphy 1995) and provide a vehicle for public-private cooperation in achieving sustainable use, sustainable conservation, and quality of life (UNESCO 1984, 1995; Kellert 1986; Ishwaren 1992; Parker 1993; Brunckhorst 1998).

Biosphere Reserve Problems

The concepts and principles of the MAB program were well ahead of their time. Implementation was hampered by the depauperate position of UNESCO internationally in the early 1980s and by greater attention and understanding being given to more charismatic programs such as World Heritage. In retrospect, it would seem that a complex and innovative idea such as biosphere reserves at a time prior to the Brundtland report (WCED 1987) and before preparations for the UNCED Rio Conference was difficult to articulate and sell to science and policy sectors, let alone more generally.

Another hurdle for the program was created in its first decade. Many nations, simply nominated to UNESCO their "special" national parks as biosphere reserves. Accordingly, Australia has 12 biosphere reserves, nominated originally for their high conservation value and research opportunities. Consequently, most of these have been operational at only one of the functional levels of a biosphere reserve, that corresponding to a core area (i.e., a national park or conservation reserve can only be a core area, although there may be a network of core areas throughout a biosphere reserve). Until recently, all were public lands alone, from which most local people felt excluded, in terms of a sense of ownership and responsibility for its well being. The broad organizational framework required for practical implementation has also been lacking.

This has exacerbated misconceptions and hampered implementation. On one hand, extreme green groups have claimed that biosphere reserve status reduced protection to a national park making it a "multiple-use" entity Conversely, some industry sectors were concerned that access over large areas would be restricted. Neither are true.

Bookmark Biosphere Reserve

Background

In Australia, two biosphere reserves have become more fully operational. These are Fitzgerald River Biosphere

Reserve in southwest Western Australia and the fledgling Bookmark Biosphere Reserve in South Australia. Originally, only one section of Bookmark - Dangalli Conservation Park was nominated —it is effectively now one of several core areas across a much expanded regional context. Uluru-Kata Juta (the "Rock") has developed uniquely and is a notable model for partnerships in indigenous cultural and natural heritage management, while Macquarie Island has developed a more specialized role in research and global climate monitoring across the world network.

Today, there is much greater understanding of ecologically sustainable development and the need for integration and management at the scale of landscape ecosystems (10s –100s km). Support and interest for the UNESCO MAB program is also growing. The increasing credibility and potential of the biosphere reserve network is now recognized in planning the main logistic base and future activities in response to the UNCED process —especially with respect to the "on-ground" implementation of Agenda 21, which needed to verify its postulates in several areas and chose the MAB program to do so. A valuable, if not crucial, attribute of the biosphere reserve concept is its flexibility and adaptability to a variety of situations. A further advantage of the program is the lack of rigid regulations, it has no legally binding status and is no threat to land holders, rural communities, or industry sectors; it encourages and supports those who wish to pursue common values and principles for sustainability. The Bookmark and Fitzgerald River Biosphere reserves are a testament to the value of such an open, flexible framework that allows it to be interpreted locally and to gather a broader influence through time.

Communities of South Australia, Victoria, and New South Wales living along the Murray River are faced with a number of environmental challenges affecting their well being. These include soil loss, landscape degradation, and species loss. Together with the infusion of saline ground waters, decreasing water quality, and disappearing wetlands -(the liver and kidneys of the River) these processes are collectively threatening the sustainability of all Riverland communities.

Productivity of this mallee ecosystem is low. The region receives an average of 240 mm of annual rainfall with annual evaporation rates potentially greater than 2300 mm. Droughts are frequent and punctuated with erratic floods. Soils are fragile and poor with deficiencies in structure and nitrogen content. The hydrology of the floodplain and wetlands of the Murray River has been altered by a variety of engineering projects designed to support agriculture and irrigation development. Problems of salinity within the ground water have been compounded by other factors including loss of deep-rooted vegetation in land cleared for timber and pastures throughout the past century. Many of the land degradation problems within the biosphere reserve are replicated on lands scattered throughout the drainage of the Murray River and its tributary, the Darling, which together drain one-seventh of the continent.

A Variety of Partnerships

Bookmark Biosphere Reserve constitutes more than 6000 km^2, which is three times the size of the Australian Capital Territory. It is made up of several different land tenures including conservation reserves, game and forestry reserves, pastoral leases, and private land. Some portions of land in the biosphere are the responsibility of the state government through the Department of Environment and Natural Resources (DENR). Another portion is the responsibility of the federal government — the Calperum Pastoral Lease, which was purchased with funds provided jointly by a Chicago benefactor and the federal government. Several other pieces of National Trust and private land also make up the biosphere reserve. In joining this collective together, governments have vested the community with the ownership and responsibility for selecting goals for management of this entire regional landscape.

The floodplains of Bookmark Biosphere Reserve are recognized as internationally significant wetlands for waterfowl and migratory species. Australia is a party to several international conventions for the protection of these areas. The Calperum Pastoral Lease, which incorporates many of these wetlands of international significance, is also the focal point for the community to experiment with novel sustainable industries. However, large-scale landscape recovery and species restoration are necessary and integral to the pursuit of ecologically sustainable development initiatives.

The Riverland communities, through nominated representatives, manage the land within the biosphere reserve and accomplish required tasks through a citizens committee, the Bookmark Biosphere Trust. The community-based trust is constituted under the South Australian National Parks Act. The trust is the formal management body responsible for Bookmark Biosphere Reserve. State (DENR), federal (formerly the Australian Nature Conservation Agency), and private sector professionals serve the trust in understanding and implementing management options.

In June 1995, Bookmark Biosphere Reserve was officially recognized and listed by UNESCO. In making its decision, the Director General of UNESCO, Dr Federico Mayor, who had recently visited Bookmark remarked:

> I wish to highlight the innovative mechanisms which have been developed to involve all stake holders in the management of the area and which could serve as an example to other sites in the world network.

While there is strong bipartisan political commitment to the future of Bookmark, governments do not have sufficient resources in the long term to recover degraded land and carry out the conservation programs that are the basis for the biological and cultural heritage of the Riverland. There are benefits to a lack of resources. If the community feels strongly about a particular course of action, it must share the responsibility for implementing it. In the process the Bookmark Trust comes to understand the program well, develops its own networks and capacity-building partners, and is able to market the program effectively through out the broader community. This, in turn, increases community participation and public-private sector support.

The Bookmark Biosphere Trust is an innovative and far sighted group of citizens concerned with the long-term sustainability of the natural environment, social values, and standard of living in the Murray Riverland of South Australia. This is indeed a bold commitment to support a "bottom-up" culture of capacity to accomplish conservation goals with few resources, political harmony, and new productive and innovative working relationships to leverage available resources, commitment, and talent. This synergy provides for resource and capacity building from the bottom-up (community), top-down (government) and sideways-in (private sector).

Such commitment is further demonstrated by the community and the private benefactor who helped with the purchase of Calperum Pastoral Lease. Most recently, Mr. Brooks McCormick has contributed a further $1.1 million to build an environment center to show case Bookmark Biosphere Reserve programs for innovative land management, conservation, ecologically sustainable development, environmental education, and community participation. The Riverland community provided the concept for an environment center assisted by the pro bono services of several professionals. The town of Renmark has donated a wetland site for the center and will provide approximately $100,000 worth of utility service connections.

Sustainability in a low productivity landscape?

The main sources of income in the mallee Riverland are pastoral development and horticultural crops. Pastoralism is not economically viable in the dry rangelands when international wool prices are low. It would also seem ecologically unsustainable during times of drought. Cropping and agriculture is based on the provision of irrigation water from the Murray River. During dry periods, the salinity of the river water is nearing the tolerance limit for citrus, the major crop. Therefore, in addition to land recovery, new enterprises for sustainable production will be required to support Riverland communities in the future (see also Freudenberger and Freudenberger 1994, Fitzhardinge 1994, Landsberg et al. 1995).

To support land management programs, the Bookmark Biosphere Trust is faced with the creative challenge of experimenting with and establishing a suite of novel resource uses compatible with conservation and land recovery. With the support of the Williamson Fellows, a group of citizens grappled with the meaning of ESD to the Riverland. They considered a range of social justice and environmental principles and came up with a provisional list of industries. This left the Bookmark Trust, assisted by its public and private sector partners, with the task of working through the ramifications of developing experimental applications of ESD in the real world —for which there are very few examples to draw upon.

This is complex enough, but is compounded by the limitations of a low productivity system, existing environmental debt, water quality issues, employment and training needs, and economic feasibility. While several potential ESD activities were considered, two— ecotourism and diversified animal products were chosen for initial trials.

The diversified animal products processing operation is based on the possibility of utilising resources that will decrease pressure on plant and aquatic communities to aid environmental recovery while providing some socio-economic benefit.

Feral goats (numbering in excess of 15,000 in the past two years) damage vegetation on the biosphere reserve. The goats are costly to remove, but could generate money if the meat and leather could be sold. Eradication is impossible (see Freudenberger 1993). However, if partial eradication caused goat numbers to fall below a density that was economically viable to remove, harvest would become uneconomical and population numbers would rise again within a few months.

Kangaroos also occur in large populations in this altered pastoral landscape, reaching densities in excess of 25 per km^2. A diversified meat processing industry, combining sustainable kangaroo harvesting and goat removal might maintain a steady supply of meat to a local abattoir and provide a few jobs (see Caughley et al. 1987).

If ESD means that the allowable annual harvest is only the nitrogen and energy fixed by the system in a given year, such a low productivity landscape may not generate enough goats and "roos" within the biosphere reserve to meet western economic requirements for investment return, and cover costs of interest repayments, depreciation of equipment, insurance, holiday pay, etc. Highly productive landscapes are more capable of meeting the needs of investor economics.

However, four other factors may contribute to socio-economic viability. First, if nitrogen and energy fixed are used directly by people living in or around the biosphere, the landscape might support the activity as an ESD. Second, the resource pool of goats and kangaroos actually emanates from the biosphere reserve and beyond (a small change in South Australian law has allowed goats to be considered in this way). Hence low productivity is partly compensated by expanding the scale or area from which resources are harvested. Third, if the industry is further augmented with bone discarded by local butchers, and carp are also harvested, a variety of prime cuts, pet food, fish meal, leathers, small goods, and blood and bone fertilizer can be produced out of a single facility. Most of these items have existing or developing market opportunities.

Finally, the challenge before the community and its partners is to communicate values for the creation of environmental health, training, jobs, and a local industry that helps recover environmental debt by reducing disturbance and grazing pressure.

Such a novel, "restorative economic" ESD model is likely to best be understood and appreciated by the foundation community. Philanthropic capital would secure a debt-free industrial basis of support to establish such ESD industries on a solid footing for a sustainable future. This support is now being gathered. In the meantime, restoration projects and monitoring programs for land in the biosphere reserve are essential in the development and evaluation of the role ESD might play in funding land management, including the recovery of environmental debt in Bookmark Biosphere Reserve.

CONCLUSIONS

Biodiversity is under threat, but the interdependence of life, together with the productivity of the land means that the harmony of society is also threatened. This is equally the case across the rangelands of Australia, the great Murray-Darling Basin, and the Riverland communities of South Australia. Many elements of Australia's ancient landscape, its river systems, and its biota require nurture and repair.

Increasingly, it is necessary to entwine strategies for ecologically sustainable development and conservation. The nature of the task at hand means that traditional approaches and the already stretched resources of the public sector, while essential, cannot do the job alone. In partnership with government, rural communities must endeavour to assemble a multitude of cross-sectoral resources, professional capacities, and volunteer contributions to develop and experiment with creative approaches to conservation and landscape recovery.

The Biosphere Reserve Program facilitates such an integration of cultural needs and aspirations for quality of life with the conservation of biodiversity. It gives local communities new responsibilities for their own sustainable future while providing a thread to re-sew peoples' identity to the landscape.

A broad-based, action-centered network of capacities can greatly contribute to an integrated, multi-disciplinary approach to conservation and sustainable development. Community partnerships and strategic alliances with the private sector and government agencies can greatly increase the variety of resources and professional capacities that can be directed towards on-ground solutions. Bookmark Biosphere Reserve is one developing model in the mallee and Riverland of South Australia. The Riverland community has committed itself to reversing degradation of environmental quality and to maintaining quality of life for their children's children. Novel approaches to integrated land management, restoration, and ESD enterprizes are being tested by local people with the assistance of public and private partners.

The world network of biosphere reserves will increasingly become important reference sites in global monitoring systems (e.g., global climate change, DIVERSITAS, SCOPE, IUBS, GTOS) in addition to being the only available mechanism for on-ground implementation of the aims of the Convention on Biological Diversity. It is hoped that other models might be fostered and perhaps join the UNESCO program.

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BIOREGIONALISM: A STATE OF MIND, PLACE, AND HEART

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ABSTRACT: In our highly mobile, technology based society, there has been a significant loss of identity with native landscapes, bioregions, and natural communities. Bioregionalism is a concept describing a sense of place, an identity with an ecosystem, its physical geography and biological diversity. A tandem theory, bioculturalism, describes the intimate connection of human cultures with the land where they live. These age-old concepts were known experientially by many native peoples before the Industrial Revolution. The head-long drive to control wilderness, extract resources, and manage landscapes has resulted in physical as well as spiritual loss. Our "high tech" lifestyles and extremely mobile society have further severed our ties with the natural world. The author discusses the implications of this separation and emphasizes the importance of fostering personal connections with a bioregion. Bioregionalism and bioculturalism are fundamental in our work as interpreters and environmental educators. Encouraging a bioregionalist outlook in our programs will enhance efforts towards long-term restoration of our native ecosystems. As people strengthen personal bonds with the land where they live, there will be stronger and more widespread commitment to the health of that land.

INTRODUCTION

An Ohlone Indian, it is said, typically spent his entire life within a 12-mile radius of his birthplace along the coast of California (Margolin 1978). A Navy officer and her family may make 15 moves along both coasts of North America during a 25-year career, with tours of duty overseas as well (De Prez, pers. comm). A Mohawk knows the spot where his umbilicus is buried (MacLeish 1994). Most modern Americans are lucky to know the name of the hospital where they were born; knowing in which dumpster the umbilicus ended up is nearly impossible.

There is a striking contrast between these lifestyles. Equally remarkable are the ramifications of these different lifestyles. "Bioregionalism" and "bioculturalism" are two terms that describe these socio-cultural phenomena, joining the plethora of "isms" that attempt to categorize or explain lifestyles and worldviews - from "wildernism" to Muir-inspired "biocentrism" to Edward Abbey's "earthism" to "ecofeminism" of the 1970s and beyond. These concepts are not only intriguing but bear direct relationship to our work as interpretive naturalists and environmental educators. This paper will explore the connections between bioregionalism, bioculturalism, interpretation, and environmental education.

DISCUSSION

Bioculturalism is a very basic concept: our cultural history is intimately connected with the ecology of the land where we are planted. Bioregionalism, a theory that I first became aware of during my personal six-year tour of duty along the West Coast, is articulated by poet Gary Snyder in a slim but "heavy" volume entitled *Turtle Talk: Voices for a Sustainable Future.* The bioregionalist theme, Synder explains, is "to learn our region, to declare that we are going to stay here and be at home in it, and . . . that we're going to take responsibility for it, and treat it right." He goes on to say that "the aim of bioregionalism is to help our human cultural, political, and social structures harmonize with natural systems" (Plant and Plant 1990).

I find it interesting that bioregionalism is de rigeur in the progressive environmentalist circles of the San Francisco Bay area, Chicago, and other major metropolises. This seemingly cutting edge concept is a very popular topic in Green Party polemics, environmental activist newsletters, and heady college-town bookstores. However novel the concept of bioregionalism might be to today's activists, it might seem old hat to the Ohlone, Ojibwe, Kickapoo, and other tribes. The eighteenth century Ohlone, I venture to say, were much more likely to be "bioculturally correct" than the twentieth century American family which doesn't stay put long enough to know much more than where the schools and the shopping malls are. Even the nomadic peoples of the plains, while covering thousands of miles in their lifetimes and living in different places during different seasons, were more bioculturally and bioregionally in-tune than our "high-tech-mega-mobile-cyber-smart" society today. The person who knows the very ground where his umbilicus is buried is more likely to have a concern for and commitment to that place than she who anticipates a job transfer every five years. One may surf the net in the World Wide Web, while the other is connected with the ultimate web.

I believe the age-old themes of bioregionalism and bioculturalism are integral in our work as interpreters and environmental educators. First, our own sense of identity with a region can have direct bearing on the quality of our interpretation and teaching. I indulge in a personal example: Having been born, raised, and educated in the Prairie State (Illinois) since I was knee-high to a May-apple, I found it quite a struggle to "become" an interpretive naturalist in Oregon and California. I took a shot at transferring my interpretive naturalist skills to the coastal sage-scrub of San Diego, the Cascades of southern Oregon, and the salt marshes of the San Francisco Bay, but things just didn't seem to "click." I was displaced spiritually, and my work reflected it. Although I learned intellectually about chaparral and old-growth Douglas fir forests and salt marshes and coastal redwood forests, the facts in my head did not produce interpretation from my heart. Or, to put it another way, it's hard to bloom where you are planted when you've been repeatedly uprooted. Recognition of my bioregionalism was a driving force in a major career/family move back home (hey, now there's a concept!) to Illinois. Here, I fully enjoy living and working, once again, among bur oaks and cardinals and *Silphium* and cicadas. This is not to say that interpreters will never be effective if they move to another part of the country. Many people move and successfully adopt a new bioregion. John Muir is a classic example of a naturalist able to wholly embrace a bioregion (the Sierra Nevada) very different from his place of birth and childhood (Scotland and Wisconsin, respectively).

Bioregionalism and bioculturalism are also important in terms of knowing our visitors, a prerequisite for effective interpretation and teaching. Tilden (1957) taught us to relate to the experience of the visitor—well, what is the experience of the visitor? Has she lived in this spot for decades, or is she getting calls from the local Welcome Wagon? Does he know a Blue Jay from a Bluebird—or lived here long enough to notice the difference? Does the crowd have a heart-felt connection with the landscape, or is the landscape just the background for a photo op on a family vacation? Do the people attending our programs seem to have a sense of place, while others seem displaced? How many of us in the Midwest have heard kids at the beginning of a hike ask suspiciously, even fearfully, "Are there tigers here?" Or what about adults who wonder if we have "those big hairy poisonous spiders" here. Sometimes it seems these folks have landed at our preserves from outer space, or Manhattan, or . . . California. Many people have no idea of where they are and with whom they share the bioregion. (See the *CoEvolution Quarterly's* [Winter 1981] revealing quiz, "Where Are You At?") Taking into account the visitor's bioregional awareness, or lack thereof, helps me give a better program. I believe it can increase the effectiveness for other interpreters and teachers as well.

CONCLUSIONS

Bioregionalism and bioculturalism are, fundamentally, part and parcel of interpretation and environmental education. There is a shared emphasis on the human connection with the natural world, cultural identity with the landscape, and stewardship of the land. Bioregionalists advocate "constructive, re-envisioning [of] our relations with nature, repairing . . . the damage done to natural systems, and recreating human cultures capable of flourishing in an ecologically sustainable manner through time" (Plant and Plant 1990). Interpretive naturalists and environmental educators, as well, promote awareness of interdependency and the human connection with nature. The bioregionalist, the environmental educator and the interpretive naturalist foster an understanding of the Big Picture and Homo sapiens' place in that tableau. The bioregionalist, the educator, and the interpreter all work toward a heightened sense of care, concern, and commitment—the environmental ethic that Aldo Leopold espoused. There is a common effort to encourage people to live in synch, rather than at odds, with their bioregion.

Think about what your lifestyle would be like if you spent your whole life within 12 miles of your birthplace. Ask people on your next hike or program to imagine this. It's sure to provoke thought and discussion, and will probably raise awareness about attitudes and lifestyles. It may even lead to an increased respect for the land and its myriad inhabitants. These are, after all, worthwhile outcomes of our educational and interpretive endeavors.

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THE ROLE OF GRASSLANDS IN THE DIVERSIFICATION OF LEAFHOPPERS (HOMOPTERA: CICADELLIDAE): A PHYLOGENETIC PERSPECTIVE

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ABSTRACT: Comprising nearly 25,000 described species, the Cicadellidae are one of the largest families of phytophagous insects. Although leafhoppers occur in most terrestrial habitats, they are particularly abundant in grasslands and are among the dominant groups of prairie herbivores. The earliest true leafhoppers are known from the lower Cretaceous Period and, thus, predate the origin of grasses. However, the tendency of certain subfamilies and tribes of leafhoppers to associate with grasses and grassland habitats suggests that evolution within these groups has been intimately tied to the origin and diversification of the Poaceae and to the spread of grasslands. Phylogenetic analyses of various leafhopper taxa using morphological and molecular data provide a means to assess the role of grasslands in leafhopper diversification. Such analyses reveal that much recent leafhopper diversification in temperate grasslands may be accounted for by a combination of historical changes in grassland distributions and host transfer among grass genera and species. Increasing host and habitat specialization within certain cicadellid lineages may also account for the presence of hyperdiverse genera, such as *Athysanella*, in the leafhopper faunas of temperate grasslands. Although specialization on grasses is common in only one of the three major lineages of Cicadellidae, analyses of higher taxa indicate that grass feeding has originated independently in various cicadellid lineages and may have contributed to the diversification of these groups.

Key words: Cicadellidae, leafhopper, Poaceae, grassland, herbivore, phylogeny, biogeography, insect-plant interactions

INTRODUCTION

Although the grass family, Poaceae, arose no later than the Eocene Epoch (56.5 million years (Ma) ago; Crepet and Feldman 1991), and perhaps as early as the Cretaceous (Linder 1987), grasslands did not become widespread until the Oligocene (30–32 Ma ago; Thomasson 1986, Retallack 1992). Despite their relative recency in geologic time, the origin and spread of grasslands undoubtedly had profound effects on the evolution of terrestrial animals. The role of grasslands in the evolution of large mammals has been well documented by numerous studies of abundant fossil material (reviewed by Webb 1985 and Stucky 1990), but the changes in patterns of diversity of other, less well-studied, groups may have been equally dramatic. The insect faunas of grasslands differ markedly from those of forests, suggesting that the spread of grasslands coincided with the origin of many new species, genera, and even family-group taxa. In particular, certain groups of insect herbivores are largely restricted to grassland habitats and specialize on grasses or other grassland plants. The fossil record of such groups is poor, so patterns in their evolutionary diversification must be inferred by gathering data on their present distributions and host plants, and by estimating their relationships using phylogenetic methods.

One such group is the family Cicadellidae (leafhoppers). In terms of species diversity and numbers of individuals, the Cicadellidae are one of the dominant groups of grassland insect herbivores (Whitcomb et al. 1988). Of the approximately 25,000 leafhopper species described, over 8000 are associated with grasslands, mostly in temperate and subtropical regions. Leafhoppers feed via piercing/sucking mouthparts on vascular fluids or, in one subfamily, on mesophyll tissue (Backus 1988), and oviposit directly into the living tissue of their host plants; consequently the timing of egg hatch and development is closely tied to host plant phenology. Although a few leafhopper groups have been well studied, very little ecological information is available for the vast majority of species. Thus, the present attempt to outline general evolutionary patterns for the family is somewhat premature. Nevertheless, information from a few detailed studies of North American leafhoppers, as well as data drawn from scattered taxonomic and ecological studies from other parts of the world, seem sufficient to form some preliminary hypotheses that may help focus ongoing efforts to elucidate the factors that contributed to leafhopper diversification.

DISCUSSION

Hypothesized Evolutionary Scenario

Current geographical distributions and the few available fossils suggest a hypothetical scenario of the timing of leafhopper diversification. The oldest undoubted

Cicadellidae from the lower Cretaceous of Australia, North and South America (Oman 1937; Hamilton 1990, 1992; Shcherbakov 1992) are difficult to place because they mostly lack obvious synapomorphies that would unite them with modern subfamilies. In contrast, Tertiary leafhoppers of Oligocene to Miocene age are often indistinguishable from modern genera (Scudder 1890; Heer 1853a, b; Dietrich and Vega 1995). Therefore, much of the subfamily- through genus-level diversification of Cicadellidae apparently occurred between the lower Cretaceous and middle Tertiary periods. Leafhopper fossils from the Upper Cretaceous, Paleocene, and Eocene are scarce. Nevertheless, many modern subfamilies, e.g., Idiocerinae, Coelidiinae, Ledrinae, Cicadellinae, and Typhlocybinae, have pantropical distributions, suggesting that they arose prior to the breakup of Pangea during the Cretaceous. Other leafhopper subfamilies are largely or entirely absent from one or more continents, suggesting a more recent origin.

Based on available host data, specialization on grasses appears to be largely restricted to a few closely related leafhopper subfamilies, including Deltocephalinae, Eupelicinae, and Aphrodinae (*sensu* Oman et al. 1990). A few other leafhopper subfamilies, e.g., Cicadellinae and Typhlocybinae, include grass-feeding species, but few of these appear to be strict specialists on grasses. The largest leafhopper subfamily, Deltocephalinae, comprises 23 tribes (Oman et al. 1990), all but 2 of which occur largely in the Holarctic, and approximately 61% of described deltocephaline species are restricted to this region. The high levels of diversity and endemism of Deltocephalinae in the Holarctic as compared to other biogeographic regions (Oman et al. 1990), and the absence of Deltocephalinae from the fossil record prior to the Oligocene, are consistent with the hypothesis that the group originated in Asia or North America, regions where grasslands first became widespread (Janis 1993).

The majority of North American grassland leafhopper species for which host data are available appear to have host ranges restricted to one or a few closely related plant species, mostly grasses (Whitcomb et al. 1988). Using Oman's (1949) intuitive diagram of relationships among the North American "Deltocephalini" (*sensu lato*, comprising tribes Athysanini, Cicadulini, Deltocephalini, Doraturini, Fieberiellini, Opsiini, Scaphoideini, and Stenometopiini of Oman et al. (1990), Whitcomb et al. (1986) noted an apparent trend from utilization of woody hosts in plesiomorphic genera toward increasing reliance on grasses in more derived members of the group. These observations suggest that specialization on grasses contributed to the diversification of deltocephaline leafhoppers (Whitcomb et al. 1986). Within the tribes Deltocephalini, Doraturini, Cicadulini, Paralimnini, and Stenometopiini (*sensu* Oman et al. 1990), most genera are restricted to grasses and many (e.g., *Athysanella*, *Elymana*, *Flexamia*, *Graminella*, *Laevicephalus*, *Polyamia*) appear to include mostly host-specialist species. Evolutionary diversification within host-specialist lineages may have occurred through host transfers that restricted gene flow among populations and thus permitted closely related species to coexist on different hosts in the same habitat.

METHODS

Testing the Scenario

One way to test hypotheses regarding the roles of various ecological factors in species diversification involves first constructing an estimate of relationships among the taxa in question using independent data and then, using parsimony criteria (Sober 1988), mapping the distributions of various ecological traits on the resulting phylogeny. In this way, the hypothesis best fitting the available data may be identified. Thus, phylogenies derived using morphological or molecular data provide a framework in which the evolution of ecological traits, such as host and biogeographic ranges, may be better understood. Unfortunately, the phylogenetic relationships among leafhoppers overall remain very poorly understood. Nevertheless, recent phylogenetic analyses permit preliminary tests of some of the hypotheses outlined above. Analyses of species-level relationships will illustrate recent patterns of diversification, while analyses of family-group taxa may elucidate patterns in the early evolution of leafhoppers.

Recent Events

The genus *Flexamia* DeLong (Deltocephalini) comprises 41 species, all of which are restricted to North American grasslands and feed almost exclusively on grasses. Host and geographic ranges for most *Flexamia* species are well known due to extensive field work by Whitcomb and Hicks (1988). They found that many species are restricted to individual genera or species of grasses and that few occupy the entire range of their host plant. Thus, Whitcomb and Hicks surmised that diversification in the genus resulted from a combination of host transfers and geographic isolation among ancestral populations. To test this hypothesis, Dietrich et al. (1997) estimated phylogenetic relationships among *Flexamia* species using mitochondrial (mt) DNA sequences. Maximum likelihood, maximum parsimony, and neighbor joining analyses of 1496 nucleotides, comprising 531 informative characters, from the 16S and NADH dehydrogenase 1 genes yielded a robust estimate of relationships (Figure 1). A maximally parsimonious map of host associations onto this tree reveals that closely related *Flexamia* species tend to utilize the same or closely related hosts. This suggests that the early diversification in the genus involved host transfers, but that most later speciation events occurred on the ancestral host and must have involved other factors, such as geographic vicariance (allopatric speciation). Approximate times of divergence for sister species in most of these host-specialist lineages, estimated using an mt DNA molecular clock (Brower 1994), range from 0.57 to 2.36 Ma ago. Thus, habitat fragmentation during Pliocene/Pleistocene glacial cycles, which began ca. 3 Ma ago (Briggs 1995), may have played a role in speciation, although such speciation events apparently occurred prior to the most recent glaciations (10-20 Ka ago). These results confirm the The genus *Athysanella* Baker (Doraturini), which includes over 150 species, apparently exhibits patterns of host associations similar to those of *Flexamia*. Morphology-based phylogenetic analyses (Blocker and Johnson 1988, 1990) tended to group *Athysanella* species associated with the same host, and species within these host-specialist lineages tend to be geographically disjunct. Thus, diversification through a combination of host shifts and geographic vicariance may prove to be a general pattern among host-specialist grassland leafhoppers.

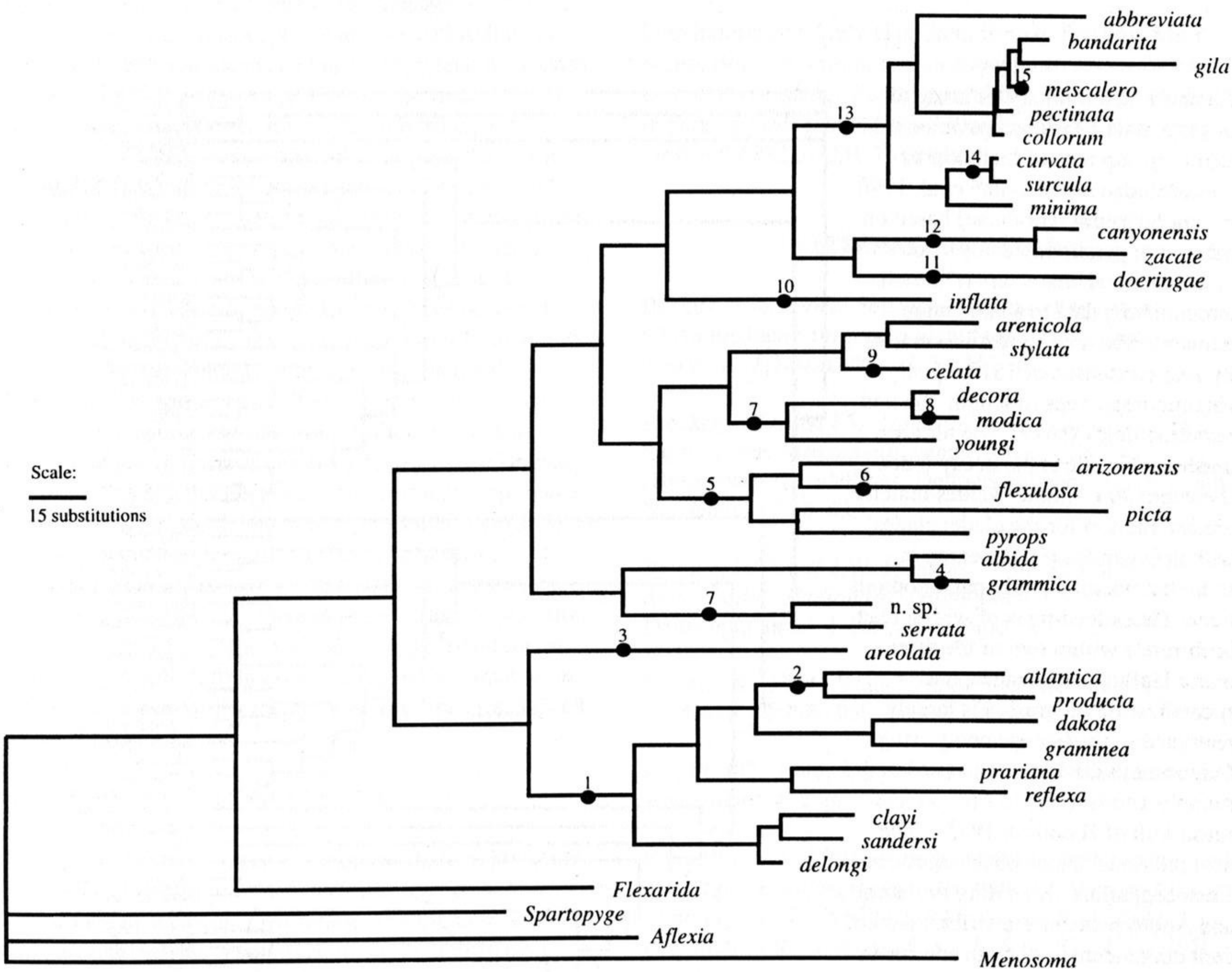

Figure 1. Evolution of host associations in the North American grassland leafhopper genus *Flexamia* (Cicadellidae: Deltocephalinae) based on the maximum likelihood estimate of cladistic relationships by Dietrich et al. (1997). The tree was derived from a dataset comprising combined mitochondrial 16S and NADH 1 dehydrogenase sequences for 37 *Flexamia* species and representatives of four outgroup genera. Host plant associations were mapped onto the tree using MacClade (Maddison and Maddison 1992) with DELTRAN optimization (parallelisms preferred over reversals): 1, shift from chloridoid to andropogonoid grasses; 2, shift to chloridoid grasses; 3, shift to *Eragrostis spectabilis*; 4, shift to *Calamovilfa* spp.; 5, shift to *Aristida* spp.; 6, shift to *Bouteloua gracilis*; 7, specialization on *Muhlenbergia richardsonis*; 8, shift to *M. repens*; 9, shift to *Redfieldia flexuosa*; 10, broadening of host range to include pooid grasses and *Juncus* (Juncaceae); 11, shift to *Bouteloua curtipendula*; 12, specialization on *M. porteri*; 13, shift to *Bouteloua* spp.; 14, shift to *Buchloë dactyloides*; and 15, shift to *M. pauciflora*. The hosts of the outgroup genera closest to *Flexamia* are *Sporobolus heterolepis*, *Bouteloua* spp., and *Muhlenbergia arenacea* for *Aflexia* , *Spartopyge,* and *Flexarida,* respectively, so the immediate ancestor of *Flexamia* was apparently associated with chloridoid grasses, possibly *Muhlenbergia* spp.

Early Divergences

The large size of the family and its worldwide distribution have hindered previous attempts to estimate the phylogeny of Cicadellidae as a whole (Wagner 1951, Ross 1957, Hamilton 1983). These studies incorporated few characters and taxa, and produced little consensus regarding relationships. The availability of fast computers and efficient phylogenetic analysis software has made more extensive analysis feasible and work is currently underway on a morphology-based phylogeny of leafhopper subfamilies (Dietrich, unpublished; data available from the author upon request). Parsimony analysis of a matrix of 93 morphological characters and 73 taxa representing the 41 cicadellid subfamilies (Oman et al. 1990, Godoy and Webb 1994) the primitive treehopper family Melizoderidae, and the outgroup Cicadidae (cicadas) and Cercopidae (spittlebugs) grouped the majority of the leafhoppers into 3 major lineages (Figure 2). Two of these lineages (Equeefini-Phereurhininae and Hylicinae-

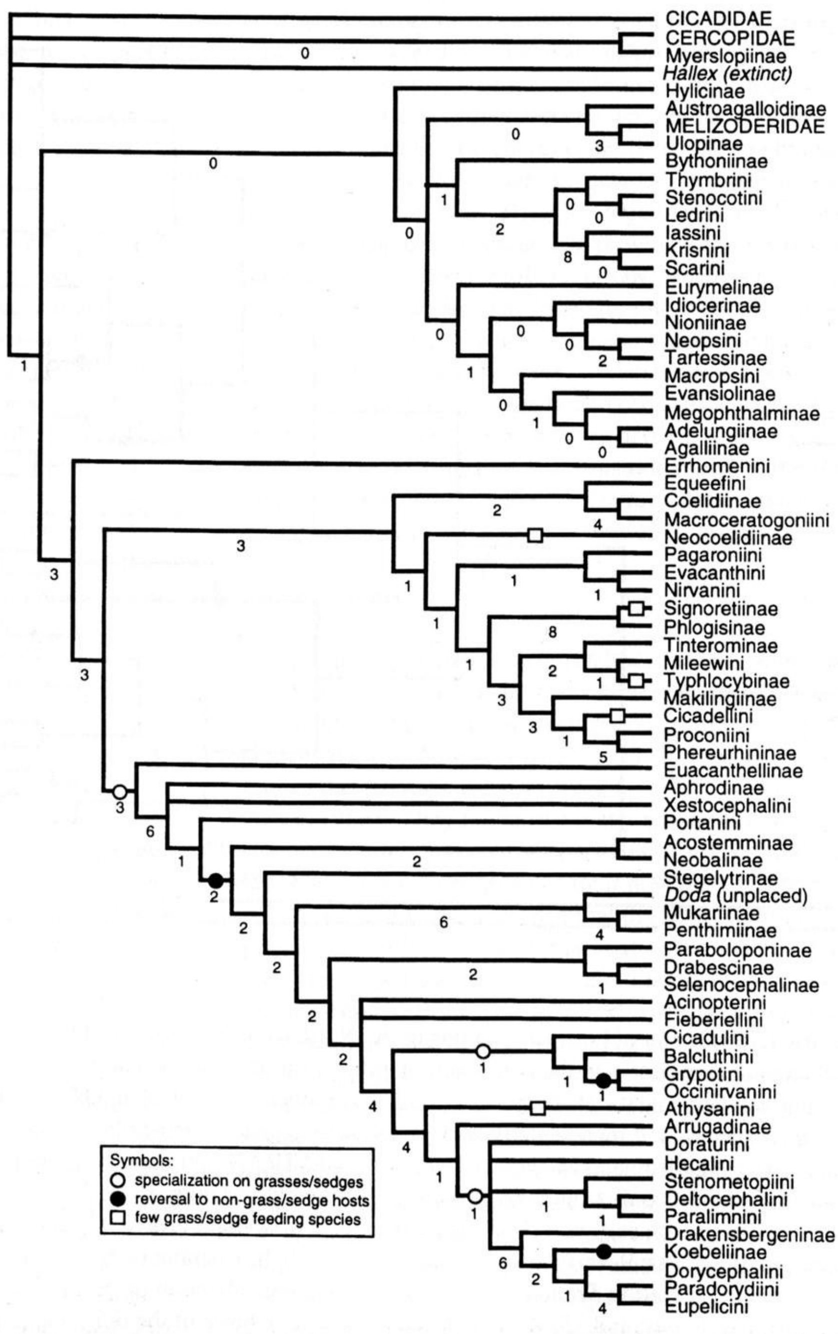

Figure 2. Preliminary estimate of phylogenetic relationships among the family-group taxa of leafhoppers (Cicadellidae *sensu* Oman et al. 1990, except Scarini=Gyponinae) based on maximum parsimony analysis of 93 morphological characters (Dietrich, unpublished; data available upon request). The tree shown is a majority-rule consensus of 1512 equally parsimonious trees of length 706 and retention index 0.619. The number under each clade is the decay index (Bremer 1994); higher values indicate greater support for the clade; clades with decay index = 0 appeared in some but not all equally parsimonious trees. Grass feeding is of widespread occurrence within two of the three major leafhopper lineages, but specialization on grasses is largely restricted to the lineage comprising Euacanthellinae-Eupelicini (which roughly corresponds to Aphrodinae *sensu lato* of Hamilton 1975). The host relationships of Euacanthellinae, Xestocephalinae (including Portanini), and Aphrodinae (*sensu stricto*) are not well documented although species in these groups occur predominantly in grasslands and apparently feed on grasses; thus the initial derivation of obligate grass feeding in the common ancestor of Euacanthellinae and its sister clade is speculative.

Agalliinae) comprise predominantly tropical or Southern Hemisphere groups largely associated with forests. A third lineage (Euacanthellinae-Eupelicini), including a polyphyletic Deltocephalinae (*sensu* Oman et al. (1990): tribes Acinopterini, Fieberiellini, Cicadulini, Balcluthini, Grypotini, Athysanini, Doraturini Hecalini, Stenometopiini, Deltocephalini, and Paralimnini) comprises groups mostly associated with temperate and subtropical grasslands, including nearly all of the leafhopper species known to specialize on grasses. Although the most plesiomorphic members of this lineage (Euacanthellinae, Xestocephalinae, and Aphrodinae) are associated with grasslands and apparently feed on grasses, several included groups (e.g., Paraboloponinae, Selenocephalinae, Penthimiinae, Stegelytrinae) retain associations with woody hosts. This implies that colonizations of grassland habitats occurred multiple times within the lineage. Grass specialization apparently arose independently, possibly four or more times, in various clades. Reversals from specialization on grasses to association with woody hosts also may have occurred (e.g., in Koebeliinae). Thus, the linear trend from woody to grass host associations within "deltocephaline" leafhoppers suggested by Whitcomb et al. (1986) may have been an oversimplification. Although, the cladogram presented here is certainly biased by the limited sample of taxa included, the tendency of leafhopper taxa associated with grasslands to group together on this tree is consistent with the hypothesis that the colonization of grasslands coincided with the derivation of one of the three major lineages of Cicadellidae. Further exploration of the role of grasses and grasslands in the evolution of leafhopper family-group taxa will require separate, more detailed analyses of the major cicadellid lineages, as well as more host plant data.

CONCLUSIONS

Viewed within a phylogenetic framework, host plant and biogeographic data provide a means to assess the role of grasslands in leafhopper evolution. Preliminary analyses suggest that species-level diversification of grassland leafhoppers occurred through a combination of host specialization, host transfers, and geographic vicariance, possibly coinciding with glacial cycles. Factors that contributed to the origins of leafhopper family-group taxa remain unclear, but the diversification of one major lineage may have coincided with the colonization of the newly dominant grassland biome in the Northern Hemisphere during the Oligocene. These hypotheses may be tested by more detailed phylogenetic analyses of individual leafhopper lineages, but more data on host associations are also needed.

In recent times, prior to the advent of intensive agriculture, grasslands occupied 40% of the earth's terrestrial surface (Clements and Shelford 1939). As human pressures on native grasslands increase, opportunities to examine interactions between grassland plants and their insect herbivores within an evolutionary framework become more fleeting. This lends an increased sense of urgency to the study of native grasslands and their role in the evolution of terrestrial biodiversity, particularly in groups for which the fossil record is poor.

ACKNOWLEDGMENTS

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EFFECTS OF PRESCRIBED FIRE ON SNAG TREE DENSITY AND QUALITY

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ABSTRACT: Snag trees are important for wildlife for nesting and feeding. A random sample of 60 snag trees each in 3 prescribe-burned and 3 unburned sites found significantly lower snag densities between burned and unburned areas (matched pair test, $t = 2.3552$ $P < .20$). Decay stage of snags also appeared to be dependent on burn history ($X 2 = 30.29$ $P < 0.05$) and is accelerated in burned units. Further, higher quality snags were found in burned areas vs. unburned as based on snag height and diameter. Therefore, snag trees are affected by prescribed burning and managers should consider steps to prevent the loss of the highest quality snag trees in frequently burned units.

Key words: snags, burn, density

INTRODUCTION

Snags, or dead standing trees, are an important part of a woodland ecosystem. Numerous bird species use snags for roosting, nesting, and feeding (Scott et. al. 1977). Primary cavity-nesting birds, such as woodpeckers, create cavities by chipping through the outer sapwood and then enlarging a cavity in the heartwood of snags. Secondary-nesting animals use existing abandoned holes in snags. Snags support a large number of insects and other arthropods, providing excellent foraging habitat. Snags also provide hunting perches for many species of birds (Raphael 1989), and are used by several mammal species for nests or dens (Thomas et al. 1979). Therefore, it is important that natural resource managers retain a sufficient number of snags for wildlife use. Different species of birds differ in the adaptations necessary to excavate holes. Hairy woodpeckers *(Picoides villosus)* can excavate holes in sound wood, while the downy woodpecker (*P. pubescens)* excavates only in softer, partially decayed wood. Bird species also prefer different height and diameter size snags for nesting. For these reasons, snags in an ecosystem need to vary in their state of decay and their size.

There is a wide variance in the recommended number of snags that should remain standing (Dove 1988). Devlin and Payne (undated) propose retaining 2.5 to 12.4 snags per ha (1 to 5/a) in Pennsylvania woodlands. Scott et. al. (1977) recommend that 5 snags per ha (2/acre) be retained in the forest interior and 7.4/ha (3/acre) remain if the woodland is within 150 m (500 ft) of water and forest openings. Bodies of water and forest edges adjacent to openings offer increased foraging opportunities for many animals. This in turn, allows for a higher density of nesting animals. Because most DuPage County, Illinois, woodlands are within 150 m of water and/or forest openings, we suggest retaining 10 to 15 snags per ha (4 to 6 per acre) with diameters greater than 13 cm and heights greater than 3 m as the minimum standard to benefit wildlife in DuPage County woodlands.

For the past ten years, the Forest Preserve District of DuPage County has used prescribed fire to manage woodland ecosystems. During the district's recent prescribed fire season, it was noticed that a large number of snags had succumbed to fires and fallen. Because snags lack the natural fire resistance of live trees, they are at risk for catching fire during a prescribed burn. The decision of how to put out the fire on a snag is largely an economic one. Fire crews evaluate the snag to determine the most efficient way of extinguishing the fire. Often this involves cutting down the snag to make it easier and less time-consuming to extinguish the fire.

This apparent drop in the number of snags in woodland management units has led to two questions: 1) What is the density of snags in units that have been managed with prescribed fire compared to those that have not been burned? and 2) What can be done to minimize this loss, if it is a problem? Answering these two questions will allow specific management recommendations to be made to prescribed fire crews regarding snag management during woodland bums.

While there may be fewer snags in previously burned units compared to unburned units, both probably contain sufficient snags for use by wildlife. Therefore, the null hypothesis is that there is not a significant difference in the number of snags available for wildlife in burned versus unburned woodlands.

Site Description

The study was conducted on three pairs of sites within the Forest Preserve District of DuPage County, Illinois. The sites were chosen to represent the different types of woodland burn management units within the county. Each pair contained a previously burned site and an unburned site. The sites were paired based on similar size, forest composition, topography, and fire prescriptions.

The study sites ranged in size from 5.8 ha (14.4 acre) to 27.2 ha (67.1 acre). Two of the three pairs contained adjacent sites, Savannah East (burned) and Maze Woods (unburned) in the Waterfall Glen Forest Preserve, and Northwest Quarter (burned) and Southwest Quarter (unburned) in the Egermann Woods Forest Preserve. The third pair of sites were located in different preserves. The burn-managed site is Pond Woods in the Greene Valley Forest Preserve; the unburned site, Upland Woods, is located in Fullersburg Woods. The Pond Woods and Upland Woods sites are quite similar in size, topography, and forest composition and provided a good comparison, despite their being located in different preserves.

The trees in each of the study areas are typical of northern Illinois oak/hickory woodlands. The dominant trees species are: white oak *(Quercus alba),* northern red oak *(Q. rubra),* black oak (Q. *velutina),* and shagbark hickory *(Carya ovala).* Secondary trees include: American elm *(Ulmus americana),* slippery elm (U. *rubra),* box elder *(Acer negundo),* black cherry *(Prunus serolina),* and hawthorn *(Crataegus spp.).*

METHODS

On aerial photographs of each site, which varied in scale from 1:1200 to 1:6000, a series of N-S and E-W transect lines, 35 m apart, were drawn to scale. Ten random points, located at the intersections of the transect lines, were then selected for each site. Each randomly selected point was located in the field using a compass and tape measure. The T-Square technique (Besag and Gleaves as cited by Krebs 1989) was used to sample each point whereby distances from the random point to the nearest snag and its nearest neighbor were used to estimate snag density. A snag was defined as any tree without leaves or buds, or a tree that was determined visually to be more than 50% dead at its crown. Only snags with a diameter at breast height (dbh) > 13 cm and height > 3 m were used in the study. A metric tape was used to measure the diameter of each snag which was placed into one of three diameter classes: small = 3 –24 cm, medium = 25 –37 cm, and large = 38+ cm. The height of each snag was visually estimated as: 3–6 m, 6–13 m, or 14+ m. Each snag was then assigned a quality rating by adding together the scores for height and diameter. Snags with a score of 2 were rated as average, snags with a score of 3 or 4 as good, and snags with a score of 5 or 6 as excellent. Because larger snags can support a larger variety of wildlife, snags with a diameter in class "small" were rated as average, regardless of height. Finally, snags were inspected with 10-X binoculars for the presence of existing cavities and assigned to one of five decay stages, with one being newly dead and five being the most decayed (Dove 1988). The species of each snag was recorded when it could be determined. Paired t-tests were conducted to determine whether snag densities differed between burned and unburned units.

RESULTS AND DISCUSSION

A total of 120 snags were sampled in the 6 study plots, representing 9 genera. In addition there were five trees for which the species could not be determined. Sixty-eight percent of the snags counted were of two genera, Quercus and Ulmus (Table 1). Snags per ha ranged from a low of 4.0 at Pond Woods, a burned unit, to a high of 29.6 at Maze Woods, an unburned unit (Table 2). A large range for both heights (3 –18 m) and diameters (13 –74 cm) was discovered. Likewise, the decay stage of the snags ranged from newly dead, to decayed and rotting. Mean snag height and diameter is displayed in Table 3.

Table 1. Percent of species of snags observed as a percentage of all trees sampled. The total represents all 120 snags observed in the 6 sites. The burned and unburned sites represent the 60 snags observed in each of the 3 burned and unburned sites.

	Total	Burned Sites	Unburned Sites
Quercus spp.	7.5%	6.7%	0.8%
Q. alba	10.0%	5.8%	4.2%
Q. rubra	6.7%	4.2%	2.5%
Q. velutina	12.5%	5.0%	7.5%
Q. macrocarpa	3.3%	3.3%	0.0%
Prunus serotina	9.2%	2.5%	6.7%
Ulmus spp.	7.5%	4.2%	3.3%
U. americana	16.7%	5.8%	10.8%
U. rubra	4.2%	1.7%	2.5%
Other	17.5%	8.3%	9.2%

Snag Density

The burned units had a significantly lower density of snags than did the unburned units ($T = 2.3552$, $P < 0.20$). The mean snag density on the three unburned units was 22.5 snags per ha (9.1 /acre), compared to a mean of 8.6 per ha (3.5/acre) in the three burned units. A considerably lower density of snags occurred in each burned unit, as compared to the unburned unit, in two of the three study pairs. The Pond Woods/Upland Woods pair showed a very large decrease in snag density in the burned unit (4.0/ha vs. 25.4/ha). The Savannah East/Maze Woods pair also showed a lower density of snags in the burned unit (20.3/ha vs. 29.6/ha). The Signal Hill/Egermann SW Quarter pair did not exhibit a major difference between the burned and unburned units (11.4/ha vs. 16.0/ha). However, the Signal Hill East unit did show a significant difference in snag density when compared to the mean unburned value. These results seem to indicate that the burned units did have a lower snag density than the unburned units.

Overall 62% fewer snags existed in the burned units compared to the unburned sites. The lower snag density is most likely due to snag mortality caused by prescribed fires. The lack of a considerable difference in the Egermann SW/Signal Hill pair is probably a result of the lower density of snags in the Egermann SW site, compared with the other unburned sites as this site was much lower in density than either of the other unburned units. This would seem to indicate that it probably is not representative of most unburned woodlands.

Table 2. Density of snags per ha (snags per acre) in each of the six sites, as well as the mean densities for the six combined sites, and three burned and three unburned sites.

	Snags per Hectare
All Units n=60	13.1 (5.3)[1]
Burned Units n=30	8.6 (3.5)
Unburned Units n=30	22.5 (9.1)
Egermann SW-unburned	16.0 (6.5)
Signal Hill East-burned	11.4 (4.6)
Upland Woods-unburned	25.4 (10.3)
Pond Woods-burned	4.0 (1.6)
Maze Woods-unburned	29.6 (12.0)
Savannah East-burned	20.3 (8.2)

[1] Snags per Acre

Table 3. Mean height and diameter of snags in each of the six sites, as well as the means for the six combined sites, and three burned and three unburned sites.

	Height	Diameter
	Meters	Centimeters
All Units n= 120	9 (3.6)[2]	31 (15.7)
Burned Units n=60	9 (3.4)	35 (16.9)
Unburned Units n=60	10 (3.8)	26 (12.7)
Egermann SW-unburned n=20	9 (3.6)	25 (9.3)
Signal Hill East-burned n=20	9 (3.7)	38 (15.3)
Upland Woods-unburned n=20	9 (3.5)	31 (16.0)
Pond Woods-burned n=20	10 (4.1)	41 (17.1)
Maze Woods-unburned n=20	7 (2.5)	23 (10.3)
Savannah East-burned n=20	9 (3.4)	31 (17.7)

[2] Standard Deviation

I also found a negative correlation between frequency and intensity of prescribed fires and snag density. The Pond Woods site, which had a snag density of 4.0/ha, has been burned five times since 1988. One of these fires were described in field reports as high intensity. Two others were of moderate intensity. The Signal Hill site, with a density of 11.4 snags per ha has been burned three times since 1990, with two intense fires and one of moderate intensity. The Savannah Hill East showed the highest density of snags of the three burned units, 20.3 per ha. It has been burned three times since 1989, two of which were of low intensity, and one of high intensity. This seems to indicate that the more often a site is burned and the higher the intensity of the flames, the lower the subsequent snag density.

Height and Diameter

The mean dbh of the snags in the burned units was significantly larger than in the unburned units ($T = 2.4$, $P < 0.05$.). Considerable differences also occurred in the dbh of snags in each of the three pairs, with the burned unit having a mean dbh. larger than that of the unburned unit. These differences seem to suggest that the larger snags survive the effects of fire better than smaller dbh snags. The mean dbh of the snags in the three unburned units did not show any significant differences among each other. This also suggests that the difference in snag diameter is due to the effects of prescribed fire. Larger diameter snags generally have higher moisture levels, and as a result, may better resist the tendency to ignite. Smaller diameter snags also tend to have less robust root systems, and may fall more easily than the larger diameter snags. No significant differences in the mean heights of snags were found in any of the study areas ($T = 1.5$, $P > 0.05$.)

Table 4 illustrates that the snags in the burned units had a higher percentage of snags ranked as good or excellent (68%) compared to the unburned units (48%). Because snag quality is a function of height and diameter, the generally larger diameter snags found in the burned sites resulted in those sites having fewer snags but generally higher quality snags.

Decay Stage

A chi-square contingency test rejected the null hypothesis that snag decay stage is not dependent on burn history ($X2 = 30.29$, $P < 0.05$). Therefore, snag decay stage appears to be associated with a unit's burn history. A review of the data indicates that burned units had snags in a more advanced decay stage. This result seems to suggest that the snags in the burned areas have remained standing for a longer period of time before failing to the forest floor than those in the unburned units. This is most likely due the generally larger diameter, and therefore, greater fire resistance of snags found in the burned units.

Management Implications

Because unburned sites contain fewer snags rated as excellent (21% vs. 32%) it is probably necessary to protect only those snags in the largest size classes. Snags having a dbh greater than 38 cm (15 in) and a height greater than 14 m (45 ft) should be saved in areas that have not been previously burned with a prescribed fire. The snag density in unburned areas can probably withstand an initial prescribed fire and still retain a sufficient number of snags for use by wildlife.

In previously burned units, natural resource managers should be aware of existing snag density and take steps to

Table 4. Snag quality ratings, percent of trees in each quality class in each of the six sites as well as the quality ratings for the combined sites, and three burned and three unburned sites.

	Average	Good	Excellent
All Units	42%	32%	26%
Burned Units	52%	36%	32%
Unburned Units	32%	27%	21%
Egermann Woods SE	45%	35%	20%
Signal Hill East	10%	55%	35%
Upland Woods	40%	20%	40%
Pond Woods	30%	25%	45%
Savannah East	55%	30%	15%
Maze Woods	70%	25%	5%

protect the existing snags if necessary. This is especially true in units that are below 1.6 to 2.4 snags per ha (4 to 6 per acre) because these densities are much lower than recommended. Because snags in the largest size and height classes are more useful for wildlife, protecting larger snags should take priority over smaller ones.

Steps that can be taken to minimize snag loss include wetting down the snag if water and manpower are available, raking the leaf litter from around the tree before the beginning of the prescribed burn, and burning under cooler conditions. Because there appears to be a relationship between fire intensity and snag mortality, it may be advisable to rewrite the fire prescription to call for a lower intensity burn in frequently burned units. A final, nonfire-related option to ensure maintenance of an optimum number of snags in burned units would be to mechanically create snags by girdling or injecting live trees. Any one of these options can be exercised; however, the first two are more reliable because predicting fire behavior in a precise manner to protect snags is often difficult and it may not be desirable to kill live trees in the larger diameter classes.

Since prescribed burning does result in snag tree mortality and snags are essential to wildlife, practices to protect snags may be necessary, particularly in frequently burned units if the existing snag density is lower than the acceptable parameters.

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RECENT EXOTIC WOODY PLANT INTRODUCTIONS INTO THE ILLINOIS FLORA

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ABSTRACT: Exotic species now constitute about 29% of the vascular plant known to occur in Illinois. Most are rarely encountered in natural areas, being restricted to roadsides, old fields, or other recent disturbances, disappearing as a result of successional processes. A few, however, are major plant pests, and we are presently suffering the consequences of widespread planting of several species which initially were thought to be without weedy tendencies. A few, such as *Rosa multiflora* Thunb. (multiflora rose) and various species of honeysuckle (*Lonicera* spp.), have become major problems, and increasing amounts of time, energy, and money are being spent to eradicate them. Others, such as *Euonymus alata* (Thunb.) Sieb. (burning bush), *Elaeagnus umbellata* Thunb. (autumn olive), and *Ulmus pumila* L. (Siberian elm), are currently becoming problems. Other exotic woody species are starting to appear spontaneously in the Illinois flora. Populations of *Acer ginnala* Maxim. (Amur maple), *Calycanthus floridus* L. (strawberry shrub), *Caragana arborescens* Lam. (Siberian pea tree), *Cornus mas* L. (Cornelian cherry), *Forsythia suspensa* (Thunb.) Vahl (weeping forsythia), *Phellodendron amurense* Rupr. (Amur cork tree), *Rhodotypos scandens* (Thunb.) Makino (jetbead) and *Sorbaria sorbifolia* (L.) A. Br. (false spiraea) have recently been found in Illinois. Of these, Amur maple, Siberian pea tree, and jetbead are a problem in at least one natural area.

Key words: exotic woody species, Illinois, future problems

INTRODUCTION

The Problem With Exotic Plant Species

The introduction of exotic and weedy species and their rapid spread into natural communities has had a significant impact on the biota of the midwestern U.S. (McKnight 1993). Estimates of the number of foreign species in the Midwest is between 20% and 30% of the flora (Stuckey and Barkley 1993). In Illinois, 28.7 % of the vascular plant species in the flora are exotics (Henry and Scott 1980), Ohio 23.8% (Weishaupt 1971), Missouri 23% (Steyermark 1963) and Minnesota 19.5% (Ownbey and Morley 1991). Many are agricultural and roadside weeds that are rarely problems. Some of these species, however, have become major pests while others are in the process of becoming pests, and the problem will increase in severity as new species enter the flora.

Exotic plant species commonly reduce diversity, decrease habitat for native plant species, and decrease habitat quality for the native fauna. They also compete for nutrients and water with native species, sometimes are responsible for excessive soil erosion, and sometimes are allelopatic, effectively reducing the establishment and growth of native species. Their economic impact may be enormous by reducing range and pasture quality and competing with native forest species.

Presently, non-native species constitute one of the most serious threats to natural areas (Bratton 1982, Harty 1986). Numerous articles have been written concerning exotics, documenting their spread from cultivation, speculation about their impact on plant communities, and describing various control measures. From 1981 to the present, over 50 articles related to the management or spread of exotic plants have been published in The Natural Areas Journal (Paddock 1992).

Within the past few decades there has been increased concern over the introduction of non-native species. Nearly every year more exotic plant species are reported as new for Illinois. In some instances these new introductions have completely altered the plant communities in which they occur (Bratton 1982, Ebinger 1983, Nuzzo 1994). Much of our present concern involves herbaceous species, *Lytrum salicaria* L. (purple loosestrife) and *Alliaria petiolata* (Bieb.) Cavara and Grande (garlic mustard) being the most recent examples (Thompson 1991, Nuzzo 1991, 1994). Woody species are also major pests.

The adaptive traits that enable exotic woody plant species to invade often are aided by mass plantings for landscaping. This large seed source associated with the disruption of native habitats by man, gives the invasive species a habitat within and around natural communities. This exotic invasion is usually not very obvious until environmental conditions are favorable for establishment. When the population size in an area becomes sufficiently high, the amount of seed becomes sufficiently large, and some dispersal agent (bird, wind, mammals, etc.) is present, the rapid dispersal of the exotic species takes place.

Woody Exotic species of the 19th century

Some woody exotics have been associated with the Illinois flora for more than a century and are now considered native by many individuals. One example, *Maclura pomifera* (Raf.) Schneider (Osage orange), was introduced into Illinois in 1847 as a "living fence" (Carriel 1961). At one time most of the farms of the Prairie Peninsula were surrounded by this species. Nearly all hedge rows have been removed, but the species still persists in moist pastures and fence rows (Nyboer and Ebinger 1978). Another is *Robinia pseudoacacia* L. (black locust), a species native to southern Illinois that was used for fence posts by early settlers. It was planted throughout much of Illinois, and is now a major invader of sand prairies in the west central part of Illinois, where it has been expensive to eradicate.

Common Woody Exotic Plant Species of the 20th Century

By the middle part of the 20th century many exotic species had became naturalized and some had became major invaders. Most were originally introduced for their floral, fruit, and foliage displays, but have since become pests. More common members of this group are *Rosa multiflora* Thunb. (multiflora rose), many species of honeysuckle, particularly *Lonicera maackii* (Rupr.) Maxim. (Amur honeysuckle), *Rhamnus cathartca* L. (common buckthorn), *Rhamnus frangula* L. (glossy buckthorn), and *Ulmus pumila* L. (Siberian elm).

During the past 30 years other woody species have become important invaders of native communities in Illinois. *Euonymus alata* (Thunb.) Sieb. (winged wahoo), a commonly planted ornamental used in landscaping along interstate highways, was reported as naturalized in Illinois in 1973 (Ebinger and Phillippe 1973). By 1979 it was known from eight counties in the state, and is now common in some forest communities where densities may exceed 150,000 seedlings/ha and 1,700 saplings/ha (Ebinger 1983). In a glacial drift hill prairie in Coles County, Illinois winged wahoo has attained a density of 2518 individuals/ha (Behnke and Ebinger 1989).

Another relatively recent introduced exotic species that is becoming a major pest is *Elaeagnus umbellata* Thunb. (autumn olive). Originally introduced to provide cover and supplementary food for birds and other wildlife, autumn olive was first listed as adventive in Illinois in 1972 (Ebinger 1983). This species is becoming a major pest in the southern two-thirds of Illinois, concentrations of 5225 individuals/ha have been reported in a pine plantation, 33,975 individuals/ha in a field with a thick stand of grasses and forbs, and 27,500 individuals/ha in a grazed upland woods (Ebinger and Lehnen 1981).

Woody Exotic Species that May Be a Problem in the 21st Century

Listed below are woody species that have recently become naturalized in Illinois. Whether any of these species becomes a major plant pest is not know, but if history is any guide, at least some will develop into major problems.

Acer ginnala Maxim. (Amur maple) — A native of central and northern Manchuria, northern China and Japan, Amur maple is a commonly planted ornamental in Illinois. Mohlenbrock (1986) mentioned that this species has infrequently escaped in three Illinois counties, while Ebinger and McClain (1991) found a large population of this exotic associated with highway plantations in east-central Illinois. At this site Amur maple seedlings averaged 11,667 individuals/ha and saplings averaged 4167 individuals/ha. This species, which has wind-disseminated seeds, will soon become a major plant pest.

Calycanthus floridus L. (strawberry shrub) — Strawberry shrub, a species of the southeastern U.S., was found as an understory component in a mesic wooded ravine in Jersey County, Illinois (McClain et al. 1992). It presently does not appear to be spreading from this site and rarely flowers or fruits. Its density at this site exceeds 11,300 individuals/ha, but most of the individuals are root sprouts.

Caragana arborescens Lam. (Siberian pea tree) — Native to Asia, this large shrub is rarely encountered as an ornamental in Illinois. Mohlenbrock (1986) reported that it had escaped from cultivation and was spreading, being naturalized in four Illinois counties. One small colony was recently observed at Harlem Hills Nature Preserve, Winnebago County, in a shallow ravine with other exotic species (Ebinger and McClain 1998). Numerous seedlings and small individuals to 2 m tall were observed. Obviously the seeds germinate easily, but a long-distance dispersal agent will be required before this species can become a major invader.

Cornus mas *L.* (Cornelian cherry) — This shrub or small tree to 7 m tall is native to southern Europe and Asia. A frequent ornamental in Illinois, it is particularly common in extensive plantations along the interstate highway system. Naturalized individuals have been found at Pere Marquette State Park, Jersey County, Illinois (Ebinger and McClain 1998). Seedlings are common at these sites.

Forsythia suspensa (Thunb.) Vahl (weeping forsythia) — A relatively common ornamental shrub that is native to China, weeping forsythia has been planted in the northeastern U.S. since 1833. It was found naturalized in a canyon at Matthiessen State Park, LaSalle County, Illinois (McClain and Ebinger 1995). It is very probable that the two populations found at this site were the result of asexual reproduction from the pendulous branches rooting at their tips. Although no ornamental plantings of this species were observed, this park was in private ownership until 1942, and numerous ornamental trees and shrubs were planted.

Phellodendron amurense Rupr. (Amur cork tree) — A native of eastern Asia, Amur cork tree is occasionally planted in Illinois, and has been reported as escaped in DuPage County, Illinois (Swink and Wilhelm 1994). Within the past few years individuals of this species have been found in flower beds and waste areas in Coles County, Illinois (Ebinger and McClain 1998). It produces large quantities of seed and will become a problem as it becomes more commonly planted in Illinois.

Rhodotypos scandens (Thunb.) Makino (jetbead) — A native of China and Japan, this species is planted occasionally in Illinois. Mohlenbrock (1986) reported it rarely escapes from cultivation but is naturalized in DuPage County. Recently, jetbead was found as an understory shrub at the Starved Rock Nature Preserve, LaSalle County, Illinois. At this site it is the most common understory shrub present, in some areas averaging 1838 individuals/ha (Ebinger and McClain 1998). This species is shade-tolerant, a heavy seed producer, and will undoubtedly become a major pest of forest communities in Illinois.

Sorbaria sorbifolia (L.) A. Br. (false spiraea) — Native to northern Asia from the Ural region to China and Japan, false spiraea is occasionally planted in Illinois. A population of this species was found at the Lowden-Miller State Forest in Ogle County as an understory shrub in a red pine plantation (Ebinger and McClain 1998). All individuals of the colony are root sprouts from an extensive horizontal root system originating from cultivated individuals. No flowering or fruiting individuals were observed.

CONCLUSIONS

Some of the exotic species listed above will undoubtedly become major plant pests in the future. Amur maple, Siberian pea tree, Cornelian cherry, Amur cork tree, and jetbead are heavy seed producers that are creating problems locally. As population numbers increase for these species, more seed will be produced, creating the potential for major increases in population numbers. Other taxa, such as strawberry bush, false spiraea, and weeping forsythia, rarely produce viable seed in Illinois and will probably remain a local problem.

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BARRENS OF PRESETTLEMENT LAWRENCE COUNTY, ILLINOIS

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ABSTRACT: The extent of forest, open woodlands, barrens, and prairie vegetation of Lawrence County, Illinois, was mapped using the General Land Office (GLO) survey notes of 1804, 1805, 1818, and 1819. Forest was the most extensive vegetation type covering 33.9% of the county followed by prairie (33.2%), barrens (15.4%), open woodland, (10.8%), and wetlands (4.0%). *Quercus alba* L. (white oak) was the dominant species in the forested areas with an importance value of 32.6 followed by *Quercus velutina* Lam. (black oak), *Carya spp.* (hickories), Ulmus spp. (elms), *Acer saccharinum* L. (silver maple), and *Fraxinus spp.* (ashes). In the open woodlands, white oak was also the dominant species (IV = 42.4) followed by black oak, hickories, elms, and *Quercus marilandica* Muenchh. (blackjack oak). The dominant species in the barrens was white oak (IV = 44. 1) followed by hickories, black oak, elms, and *Liquidambar styraciflua* L. (sweet gum). Tree density (trees/ha) was 155.2, 20.5, and 54.2 for the forest, open woodland, and barrens areas, respectively. The dominant species among line trees was white oak. A large prairie which bordered the Wabash River covered approximately 10 km^2. Numerous ponds were associated with old channels of the Wabash and Embarras rivers and one extensive slough, approximately 16 km long, was associated with the Wabash River. Several of these wetlands still exist.

Key words: barrens, GLO survey, presettlement, Lawrence County

INTRODUCTION

Shifts of plant community boundaries occur over extended periods of time, and the knowledge of the presettlement vegetation can be very useful in interpreting some of these changes. In particular, a comparison of presettlement vegetation with that existing at the present time allows us to estimate the degree and direction of changes during the last 150 years in central Illinois.

General Land Office (GLO) survey notes are occasionally being used to reconstruct presettlement vegetation, and when used in conjunction with other sources, such as soil surveys, and early historical accounts, provide a reasonable indication of the vegetation just prior to settlement by Europeans (Bourdo 1956, Hutchinson 1988). In Illinois, the GLO survey notes were used by Anderson (1970) to determine the extent of presettlement prairies. They have also been used to reconstruct the presettlement vegetation of Kane (Kilburn 1959), Coles (Ebinger 1987), Williamson (Anderson and Anderson 1975), and Douglas (Ebinger 1986) counties and the Mackinaw River valley (Thomas and Anderson 1990).

During the present study, the presettlement vegetation of Lawrence County, Illinois, was determined using the GLO survey notes. This county is located in the Southern Till Plain the and Wabash Border Natural Divisions of east-central Illinois (Schwegman 1973) and has an area of 967 km^2 (373 mi^2) (McCleave 1910). The Wabash River forms the eastern border of the county and the Embarras River flows through the central portion of the county from a northwest to southeast direction. An Indian boundary line delineating the west boundary of land ceded by native Americans, lies in a generally north-south orientation in the western portion of the county (Figure 1). Sixty-three individuals received allotments of land in what is now Lawrence County from the French government and were required to be "resident settlers" by 1783; however, formal settlement first occurred in St. Francisville in 1803 (McDonough Publishing Co. 1883).

METHODS

The GLO survey notes were copied from microfilm files of the original text. The data were then verified by comparing the copied notes to records at the Lawrence County courthouse. The original GLO survey was conducted in two phases. The portion of the county east of the Indian boundary was surveyed in 1804 and 1805 and the portion west of the boundary was surveyed in 1818 and 1819. Plat maps from the microfilm and court records were used to determine the extent of the forest, prairie, and wetland areas. A thorough explanation of the methods used by early surveyors is provided Ebinger (1986), Hutchison (1988), and Thomas and Anderson (1990).

The Q,1 and Q2 methods of Cottam and Curtis (1956) were used to calculate the square root of the mean area and tree densities. Approximate tree density was calculated for each section and quarter section point. Forest, prairie, and open woodland were determined using the method outlined by Anderson and Anderson (1975). Points with a tree density greater than 46.9 trees/ha (19.0 trees/acre) were considered as forest areas. Points which had a tree density less than 0.5 trees/ha (0.2 trees/acre), or were designated by "mound" or "post in mound" in the survey notes, were considered as prairie. Points with tree densities between 0.5 and 46.9 trees/ha were considered as open woodland. A large area in the eastern portion of the county and 13 section lines scattered throughout the county, designated as a barrens by the surveyors, were analyzed independently.

The total number of individuals, tree density, total basal area (m^2), relative density, relative dominance, Importance Value (IV=total score of 100), basal area (m^2/ha), and mean dbh were determined for each species or species group in the forest, open woodland, barrens, and prairie areas. Importance Value (IV) is the sum of the relative density and relative dominance and quantifies the importance of a species or species group based on the number and size of trees present. The approximate percentages of the county covered by forest, open woodland, barrens, prairie, and wetlands were estimated by dividing the number of points occupied by each vegetation type by the total number of plots. The composition and frequency (number of section lines in which a species or species group was mentioned) of the understory species in each area were also determined. The extent of each vegetation type was compared to soil survey reports (Fehrenbacher and Odell 1956) to determine if any relationship existed between soil type and vegetation type. The total number of individuals, relative density, relative dominance, IV (total score of 100), and average dbh (cm) were determined for each species or species group for line trees. The surveyor's name for each species is recorded in Table 1 along with the probable scientific name (Mohlenbrock 1986).

RESULTS

A total of 1144 section and quarter section points existed in the county. Of that number, 388 (33.9%) were located in forest, 124 (10.8%) in open woodland, 176 (15.4%) in barrens, 380 (33.2%) in prairie, and 45 (4.0%) in wetlands. No data were recorded for 31 points (2.7%). The dominant trees of the upland forests were *Quercus alba* L. (white oak), *Quercus velutina* Lam. (black oak), *Carya spp.* (hickories), *Ulmus spp.* (elms), and *Fraxinus spp.* (ashes), respectively, while *Acer saccharinum* L. (silver maple) was the dominant lowland species (Table 2). Tree density was 155.2 trees/ha (62.7 trees/acre). The most frequently mentioned species in the understory of the upland forests were *Corylus americana* L. (hazel), which was mentioned as an understory species for 93 section lines, followed by blackjack oak, hickories, black oak, and briars, respectively (Table 3). The most frequently mentioned species in the understory of the lowland forests were *Lindera benzoin* (L.) Blume (spice) (36 section lines), *Cephalanthus occidentalis* L. (pondbrush), vines, *Liquidambar styraciflua* L. (gum), and *Rosa spp.* (rose) (Table 3).

The dominant trees in the open woodlands were white oak, black oak, hickories, elms, and *Quercus mardandica* Muenchh. (blackjack oak) (Table 2). Tree density was

Table 1. Tree and understory species listed in the GLO survey of Crawford County, Illinois, and the probable scientific names. Nomenclature follows Mohlenbrock 1986.

Ash	*Fraxinus* L.
Birch	*Betula nigra* Ehrh.
Black gum	*Nyssa sylvatica* Marsh
Blackjack oak	*Quercus marilandica* Muenchh.
Black oak	*Quercus velutina* Lam.
Black walnut	*Juglans nigra* L.
Blue ash	*Fraxinus quadrangulata* Marsh.
Blue beech	*Carpinus caroliniana* Walt.
Boxelder	*Acer negundo* L.
Cherry	*Prunus serotina* Ehrh.
Crabapple	*Malus* spp.
Cottonwood	*Populus deltoides* Marsh.
Dogwood	*Cornusflorida* L.
Elm	*Ulmus* spp.
Gum	*Liquidambar styraciflua* L.
Haw	*Crataegus* spp.
Hazel	*Corylus americana* L.
Hickory	*Carya* spp.
Hoop ash	*Fraxinus nigra* Marsh.
Jack oak	*Quercus imbricaria* Michx.
Linden	*Tilia americana* L.
Locust	*Gleditsia triacanthos* L.
Mulberry	*Morus rubra* L.
Pawpaw	*Asimina triloba* (L.) Dunal.
Pecan	*Carya illinoensis* (Wang) K. Koch
Plum	*Prunus* spp.
Pond brush	*Cephalanthus occidentalis* L.
Poplar	*Liriodendron tulipifera* L.
Post oak	*Quercus stellata* Wangh.
Redbud	*Cercis canadensis* L.
Red oak	*Quercus rubra* L.
Rose	*Rosa* spp.
Sassafras	*Sassafras albidum (Nutt.)* Nees.
Silver maple	*Acer saccharinum* L.
Spanish oak	*Quercusfalcata* Michx.
Spice	*Lindera benzoin (L.)* Blume
Sugar maple	*Acer saccharum* Marsh.
Swamp white oak	*Quercus bicolor* Willd.
Sycamore	*Platanus occidentalis* L.
Water beech	(?)
White ash	*Fraxinus americana* L.
White oak	*Quercus alba* L.
White walnut	*Juglans cinerea* L.
Willow	*Salix nigra* Marsh.
Briars	*Rubus* spp.
Grape	*Vitus* spp.
Hemp	
High grass	
Vines	
Weeds	

Table 2. Species, total number of individuals, density (trees/ha), relative density, relative dominance, Importance Value, basal area (m^2/ha), and average dbh (cm) for witness trees listed in the GLO survey of presettlement Lawrence County, Illinois. The scientific names of the species are listed in Table 1.

Species	Total # of Individuals	Density (trees/ha)	Relative Density	Relative Dominance	Importance Value	Basal area (m^2/ha)	Average DBH (cm)
				Forest			
White oak	240	47.3	15.3	17.3	32.6	8.67	45.0
Black oak	88	17.4	5.6	8.8	14.4	4.42	51.3
Hickory	169	33.3	10.7	5.8	16.5	2.90	31.8
Elms	74	14.6	4.7	4.9	9.6	2.47	40.1
Maple	50	9.9	3.2	3.6	6.8	1.81	44.7
Ashes	58	11.4	3.7	2.5	6.2	1.27	87.1
Gum	40	7.9	2.6	2.5	5.1	1.26	42.4
Sycamore	7	1.4	0.4	1.1	1.5	0.50	66.0
Blackjack oak	17	3.4	1.1	0.4	1.5	0.18	22.6
Black walnut	7	1.4	0.4	0.7	1.1	0.35	45.5
Red oak	6	1.2	0.4	0.7	1.1	0.36	61.7
Honey locust	5	1.0	0.3	0.5	0.8	0.26	56.9
Cottonwood	4	0.8	0.3	0.6	0.9	0.31	61.0
Birch	4	0.8	0.2	0.1	0.3	0.05	26.7
Others (12 species)	17	3.4	1.1	0.5	1.6	0.26	28.2
Totals	786	155.2	50.0	50.0	100.0	25.07	
				Open woodland			
White oak	166	8.4	20.4	22.0	42.4	1.69	47.0
Black oak	86	4.3	10.6	15.3	25.9	1.18	55.9
Hickories	100	5.0	12.3	6.2	18.5	0.47	33.3
Elms	23	1.2	2.8	3.5	6.3	0.26	44.7
Blackjack oak	15	0.8	1.9	1.0	2.9	0.08	33.8
Others (8 species)	16	0.8	2.0	2.0	4.0	0.15	45.2
Totals	406	20.5	50.0	50.0	100.0	3.83	
				Barrens			
White oak	134	21.8	20.2	23.9	44.1	3.68	46.5
Hickories	65	10.6	9.8	6.5	16.3	1.00	33.8
Black oak	52	8.5	7.8	7.7	15.5	1.19	50.0
Elms	22	3.6	3.3	3.7	7.0	0.57	42.4
Gum	14	2.3	2.1	2.2	4.3	0.34	39.9
Blackjack oak	14	2.3	2.1	1.7	3.8	0.26	33.8
Ashes	12	2.0	1.8	1.8	3.6	0.27	40.1
Silver maple	4	0.7	0.6	0.5	1.1	0.08	38.1
Others (9 species)	15	2.4	2.3	2.0	4.3	0.32	40.9
Totals	332	54.2	50.0	50.0	100.0	7.71	
				Prairie			
Black oak	6	0.7	14.3	12.4	26.7	0.08	35.6
White oak	5	0.7	11.9	12.4	24.3	0.10	40.1
Hickories	4	0.4	9.5	6.6	16.2	0.03	27.2
Elms	2	0.6	4.8	10.2	15.0	0.16	57.2
Blackjack oak	3	0.2	7.1	3.2	10.4	0.01	30.5
Swamp white oak	1	0.3	2.4	5.2	7.6	0.08	61.0
Totals	21	2.9	50.0	50.0	100.0	0.46	

20.5 trees/ha (8.3 trees/acre). The most frequent understory species were hazel (72 section lines) followed by blackjack oak, black oak, hickory, white oak, and pondbrush (Table 3). Additionally, 26 section lines were described as being "clear of underwood" (Table 3).

The barrens in the eastern portion of the county were generally described as brushy, briary, poor to very poor land with a scattering of timber. The remaining barrens were situated on dry, level to rolling areas and were described as being thinly timbered with an understory consisting primarily of blackjack oak and hazel. The dominant trees in the barrens areas were white oak, hickories, black oak, elms, gum, and blackjack oak (Table 2). Tree density was 54.2 trees/ha (21.9 trees/acre). The most frequent understory species listed for the barrens were brush (19 section lines), briars, blackjack oak, high grass, vines, and hazel (Table 3).

No specific relationship could be established between soil type and vegetation type. Generally, the forests and open woodlands were associated with Bluford, Ava, Stoy, and Hosmer silt loam soils (Fehrenbacher and Odell 1956). These soils formed over thin loess on leached or weathered Illinoian till on slopes ranging from 0.5% to 18%.

The barrens in the eastern portion of the county were confined to an extensive ridge system that stretched across the length of the county in a north to south orientation (Figure 1). The elevation of this system ranged from 123 m to 164 m (405 ft to 540 ft). The soils of the ridge system were Bloomfield fine sand, Kincaid fine sandy loam, Billet sandy loam, Iona and Alford silt loams, and Omaha silt loam (Fehrenbacher and Odell 1956). These droughty soils developed on terraces or upland areas and often had slight accumulations of clay, iron oxide, or calcareous subsoils. Billet sandy loam and Omaha loam are droughty soils that developed under grass, but were forested at the time of settlement.

With the exception of a large, low wet prairie associated with a large slough in townships 3N and 4N, ranges 10 W

Table 3. Number of section lines in which a species was mentioned as an understory component in the forest, open woodlands, and barrens in the GLO survey of presettlement Lawrence County, Illinois. The probable scientific names of the species are listed in Table 1.

Species	Forest	Open woodlands	Barrens
Hazel	93	72	11
Blackjack oak	49	52	15
Hickory	38	20	2
Spice	36	4	1
Black oak	20	22	2
Pondbrush	14	11	3
Clear	12	26	1
Vines	11	7	12
Briars	9	—	16
Gum	9	—	—
Brush	6	—	19
Rose	6	—	—
White oak	6	11	—
Red bud	5	—	—
Silver maple	5	—	—
Grape	3	—	1
Sassafras	4	9	1
Plum	3	5	—
Willow	2	—	1
Elm	2	—	—
Ash	2	1	—
Oak	1	1	—
Haw	1	—	—
Blue beech	1	—	—
Crabapple	—	1	—
High grass	—	—	13
Scrub oak	—	—	2
Dogwood	—	—	1
Weeds	—	—	1

and 11W, and a dry gravel in T4N R 11W, the prairies were confined to level upland areas. Hazel, plum, briar, and crabapple thickets were occasionally reported in the upland prairies. The few trees listed for the prairie areas were black oak, white oak, hickories, elms, black jack oak, and swamp white oak (Table 2).

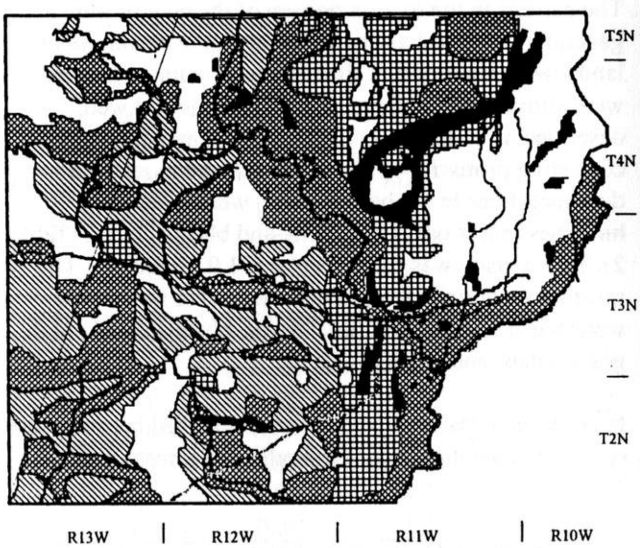
When selecting witness trees, surveyors tended to select medium-sized trees which were easier to inscribe than smaller trees and had a lower mortality rate than more mature trees. Additionally, the selection of species for witness trees was not always random (Lutz 1930). Therefore, line trees may provide a more representative sample of the composition and structure of presettlement woodlands. White oak was the dominant line tree, followed by black oak, hickories, elms, and ashes (Table 4).

Two trail systems were encountered during the survey. The Shawnee Trace traversed the southeast portion of the county in a southwest to northeast direction and the Illinois Trace traversed the central portion of the county in an east to west direction. Additionally, a "commons" on which no bearing trees existed was reported opposite of Vincennes between sections 20 and 21 in T3N R10W.

Several small ponds were associated with old river channels of the Embarras River and some are still present. Pond brush, Salix *nigra* Marsh. (willow), rose, and *Betula nigra* Ehrh. (birch) were associated with these ponds.

DISCUSSION

As discussed in other studies (Anderson 1982, Ebinger and McClain 1991), the forests in Lawrence County were confined to areas of more rugged topography associated with streams and rivers which afforded some protection



Map of presettlement Lawrence County, Illinois showing extent of forest (▒), open woodland (▒), barrens (▒), prairie (open areas). rivers, streams, and ponds (■). native American boundary ( ) Illinois Trace (___), and Shawnee Trace (_.._).

Figure 1. Map of preseetlement Lawrence County, Illinois showing approximate locations of biotic communities.

Table 4. Species, total number of species, relative density, relative dominance, Importance Value, and average dbh for line trees listed in the GLO survey of presettlement Lawrence County, Illinois. The probable scientific names of the species are listed in Table 1.

Species	Total # Individuals	Relative Density	Relative Dominance	Importance Value	Average DBH (cm)
White oak	19222.4	20.743.1	46.5		
Black oak	61	7.1	9.0	16.1	54.9
Hickories	50	5.8	6.3	12.1	36.6
Elms	33	3.9	3.5	7.4	45.0
Gum	25	2.9	3.2	6.1	51.3
Ashes	24	2.8	1.8	4.6	39.9
Silver maple	13	1.5	1.5	3.0	49.5
Honey locust	5	0.6	1.0	1.6	66.0
Sycamore	4	0.5	0.7	1.2	62.6
Black walnut	3	0.3	0.6	0.9	64.3
Cottonwood	4	0.5	0.4	0.9	45.7
Spanish oak	4	0.5	0.4	0.9	43.2
Blackjack oak	3	0.4	0.3	0.7	43.2
Others (5 species)	7	0.8	0.6	1.4	48.5
Totals	42850.0	50.0100.0			

from fire. Fires, which occasionally swept through the uplands, encouraged the regeneration of fire-tolerant species such as oaks and hickories (Rogers and Anderson 1979). Fire-sensitive mesophytes such as *Acer saccharum* Marsh. (sugar maple) were restricted to the more humid slopes where fire frequency was probably reduced.

The open woodlands were primarily limited to the areas of rolling topography, forest/prairie interface zones, and scattered timber groves in the prairies (Figure 1). As in the upland forests, white oaks, black oaks, and hickories were the dominant trees; however, elms and blackjack oak also were present. The gentle terrain of the open woodlands and their association with extensive tracts of prairie would indicate that fire probably played an important role in creating and maintaining these areas (Anderson and Brown 1983, Madany 1981, Ridgway 1873, Tester 1989, White 1994, Williams 1981). Nuzzo (1985) noted that frequent, low-intensity fires maintained an open understory, leaving the overstory trees, while infrequent, high-intensity fires killed larger trees and promoted a thicketlike growth. It is possible that the differences in the structure of the understory of the open woodlands—hazel, blackjack oak, and black oak versus understories "clear of underwood"—may be attributed to fire intensity and frequency.

Fire may have played an important role in creating and maintaining barrens. The more rugged terrain, the presence of "high grass" in the understory, and the presence of several small prairies in the eastern barrens would indicate that this area occasionally burned. However, since brush, briars, blackjack oak, and hazel were frequently mentioned, the barrens probably did not bum as frequently as the prairie areas (Nuzzo 1985). The presence of the two trail systems and the "commons" could also indicate that fire frequency may have been reduced; thus creating successional-type areas with an understory composed of hazel, blackjack, and briars within the barrens.

The barrens of presettlement Lawrence County, Illinois, were thinly timbered communities with a relatively open understory. They were generally associated with areas of nearly level to gently rolling topography and poor sandy or droughty soils that may have served to limit the forestation. These conditions, combined with periodic fires of varying intensities, probably played a major role in the maintenance of these communities.

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SMALL MAMMAL COMMUNITY STRUCTURE IN RESTORED TALLGRASS PRAIRIE

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ABSTRACT: The Illinois Department of Natural Resources (IDNR) currently manages approximately 4000 ha of natural and restored prairie. High human impacts coupled with small patch size result in challenging management decisions for prairie conservation. This study was conducted at the Middle Fork State Fish and Wildlife Area, in Vermilion County, Illinois, to describe small mammal diversity and community composition among three successional stages in restored tallgrass prairie. A total of 312 small mammals of 6 species were captured. Species included *Peromyscus maniculatus*, *P. leucopus*, *Zapus hudsonius*, *Mus musculus*, *Reithrodontomys megalotis*, and *Microtus ochrogaster*. We found a positive correlation (r = 0.66) between the diversity of plants and small mammals, with early-successional prairies having highest plant and mammal diversity. *Peromyscus maniculatus* was found at high densities in the fallow fields, where small mammal diversity was lowest. *Z. hudsonius* occurred only in early-successional prairies, suggesting a strong habitat preference for this successional stage. *Microtus ochrogaster* had significantly higher densities in the early-successional prairies than in fallow fields or established prairies. Managing natural and restored prairies as a mosaic of successional stages may be necessary to retain a full complement of native small mammals.

Key words: rodents, tallgrass prairie, small mammals, Illinois

INTRODUCTION

Illinois was predominantly prairie prior to settlement. The original prairies were a mosaic ranging from grass-forb to oak savanna communities. The prairie fauna was also diverse and included habitat generalists adapted to a wide range of communities, and specialists found only in particular ones within this mosaic. Currently about 118 ha of prairie remain for each million ha of presettlement prairie, a loss of over 99% (Illinois Department of Conservation 1976). The Illinois Department of Natural Resources (IDNR) manages over 4000 ha of diverse prairies (W. McClain, pers. comm.). Most are small remnant patches on lands unsuitable for agriculture, or land such as railroads and cemeteries. Of this acreage, approximately 25% is high-quality and undisturbed natural prairie, whereas the remainder is being restored and improved.

To conserve quality prairies and restore degraded ones, management must address the full range of ecosystem components. While strides have been made in understanding and managing prairie vegetation, far less is known about the management of prairie fauna. Accordingly, Ryan (1986) noted that an emerging goal for conservation agencies is the "conservation of wildlife species native to [all] the prairie habitats of a particular region."

Small mammals comprise an important component of the prairie fauna. They selectively consume plants, distribute seeds and spores, mix and aerate soil and detritus, and serve as prey for larger predators. Yet, because these animals are small and numerous, they are easily overlooked.

Management practices, such as seeding, burning, and mowing, can impact the density, distribution, and species composition of small mammal communities. It is well documented that successional changes in vegetation lead to changes in small mammal communities (Hansen and Warnock 1978, Huntly and Inouye 1987, Swihart and Slade 1990, Foster and Gaines 1991, Sietman et al. 1994). Huntly and Inouye (1987) found that the density and diversity of mammals were positively correlated with standing crop biomass and nitrogen content. Successional changes in prairies and grasslands may affect mammal communities by altering availability of preferred foods (Foster and Gaines 1991), foraging efficiency (Kaufman and Kaufman 1990, Clark et al. 1991), digestibility (Cole and Batzli 1979), or movements (Hansen and Warnock 1978). Specific management practices can have either positive or negative impacts depending on the species of interest, timing, and extent of disturbance (Kaufman et al. 1983, Kaufman et al. 1988, Clark et al. 1989). For example, density of deer mice (Peromyscus maniculatus) tends to increase in newly burned areas, while the density of western harvest mice (Reithrodontomys megalotis) decreases (Kaufman et al. 1983, Kaufman et al. 1988).

Numerous studies have reported habitat preferences and vegetative correlates of small mammals, but few have addressed the effects of successional changes on small mammal communities. None have addressed the effects of prairie restoration and succession on these species. The purpose of this study was to describe the density and diversity of small mammals in successional stages of restored prairie. We estimated the seasonal density and species composition of small mammals in three successional stages of tallgrass prairie, and related mammal density and composition to vegetative structure and composition.

METHODS

This study was conducted at the Middle Fork State Fish and Wildlife Area (MFSFWA) in Vermilion County Illinois, 10 km north of Oakwood. The area was purchased by the state in 1986 and consists of 1093 ha of forests, cropland, prairies, and marshes. The MFSFWA provided a unique situation in which native prairie was being restored with replicate fields in different stages of succession. It is the intent of the IDNR to restore these fields to upland tallgrass prairie and savanna. Management techniques used to produce desired plant communities include the use of prescribed burning, over-seeding, and mowing. Generally, prairies are burned on a three- to four-year cycle to establish and maintain desired vegetation.

Three different stages of restoration were selected as treatments: 1) fallow fields designated for future restoration, 2) early-successional prairies, and 3) established prairies at least nine years old. Fallow fields were dominated by cool season grasses such as smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), and goldenrod (*Solidago* spp.) and they contained substantial plant litter. Early-successional prairies were dominated by forbs (74.6%) and warm season grasses (22%) such as big bluestem (Andropogon gerardi), little bluestem (A. scoparius), and Indian grass (*Sorghastrum nutans*). Established prairies were dominated by warm season grasses (66%) with forbs interspersed. The density of ground cover was highest in the established prairies. Three fields within each treatment were sampled, for a total of nine fields. Fields were selected based on accessibility, homogeneity within each treatment, and minimal disturbance due to recreational use of the area.

Trapping was conducted over three seasons: spring (May 25 to June 4), summer (August 3 to 12), and winter (January 6 to 15). A trapping grid was established in each field. Grids were established at least 7.5 m from field edges to minimize edge effects (Kirkland 1989, Tew et al. 1994). Trap stations were established at 15–m intervals within each grid. Each field had no less than 32 trap stations and no more than 46, with an average of 40. The total area covered by grids in each treatment were 2.8 ha in fallow fields, 2.5 ha in early successional prairies, and 2.8 ha in established prairies.

Each station consisted of a single Sherman trap (160 mm x 50 mm x 65 mm) baited with rolled oats. Traps were placed in small mammal runways or under protective covers whenever possible. Polyester fiberfill was added to the traps during the winter to provide insulation. Each field was trapped for three consecutive nights during each season, a total of 3267 trap-nights. Traps were checked each morning between 6:00 and 10:00 a.m. Captures were identified by species and sex, weighed, and marked before release.

Vegetation surveys were conducted in each field in June. All vegetation within a 1-m^2 quadrat centered over each trap was recorded. The species and estimated areal cover of each plant within the quadrat were recorded.

The number of small mammals captured in each treatment and season were normalized, and a chi-square contingency test was used to test ($\mu = 0.05$) among treatments and seasons. A significant chi-square value suggested that a species selected for or against a particular treatment with a greater likelihood than would be expected by chance. Mean densities for each species in each treatment are reported as the number of individuals/ha, plus or minus one standard error. Plant diversity and small mammal diversity were calculated using the Shannon-Weiner index (H') (Shannon 1948). A nonparametric Spearman rank correlation analysis was used to investigate whether a correlation existed between mammal diversity and plant diversity in the prairie sites. Because plant diversity in the fallow field was skewed upwards by the presence of many exotic species, these were excluded from the analysis.

RESULTS AND DISCUSSION

Density of Small Mammals

A total of 312 small mammals of 6 species was captured during the three trapping seasons. There was a 7% mortality rate and a 4% escape rate. Individuals that escaped marking were not included in the data analyses. Across all seasons and stages of restoration, deer mice (*Peromyscus maniculatus*) comprised the majority of individuals captured (58%), while white-footed mice (*Peromyscus leucopus*) (13%), prairie voles (*Microtus ochrogaster*) (12%), and western harvest mice

(*Reithrodontomys megalotis*) (9%) were also common. Meadow jumping mice (*Zapus hudsonius*) and house mice (*Mus musculus*) each comprised 4% of the sample.

Small mammal communities differed in composition and density across the stages of prairie restoration. Three species showed habitat preferences: deer mice, jumping mice, and prairie voles. Deer mice were found at higher densities in fallow fields ($P = 0.04$). Deer mice averaged 34.9/ha in fallow fields, but only 20.5/ha and 19.6/ha in early-successional and established prairies, respectively. Deer mice are known to prefer habitat with open ground and relatively sparse vegetation, an apt description of our fallow fields (Hansen and Warnock 1978, Kaufman et al. 1983, Clark et al. 1989). Dense vegetation and thick litter may impede movement and decrease foraging efficiency of this species (Clark et al. 1991). Densities of white-footed mice did not differ among successional stages with 4.9 (SE = 1.8) individuals/ha in fallow fields, 5.4 (SE = 2.9) individuals/ha in early-successional prairies, and 6.3 (SE = 1.9) individuals/ha in established prairies.

Meadow jumping mice were not captured in high numbers at any location, but were found only in early-successional prairies (Table 1). This suggests a strong preference for this successional stage, and is in agreement with a previous study (Dueser and Porter 1986). Prairie voles also were found at higher densities in early-successional prairies ($P < 0.01$). The mean density of voles was 11.7/ha in these prairies, but only 1.8/ha in fallow fields and 3.3/ha in established prairies. Studies have consistently shown that the densities of voles are highest in habitats that provide extensive vegetative cover and food resources with high nitrogen and digestible energy content (Eadie 1953, Cole and Batzli 1979, Huntly and Inouye 1987). We speculate that the diversity of forbs and native, warm-season grasses found in the early-successional prairies provided the best mix of these resources.

The densities of western harvest mice generally increased with the age of the prairie, from 1.8/ha in fallow fields to 3.4/ha in early-successional prairies to 5.5/ha in established prairies, however these differences were not significant ($P = 0.09$). Neither white-footed mice ($P = 0.76$) nor house mice ($P = 0.70$) showed any differences in density among the three treatments (Table 1).

The density of small mammals varied seasonally with each successional stage of tallgrass prairie. Mammal densities have been shown to vary seasonally in several plant communities (Heske et al. 1984, Johnson and Gaines 1988, Swihart and Slade 1990). In fallow fields, white-footed mice and voles occurred at low but relatively constant densities across all seasons. However, other species exhibited strong seasonal trends. In all stages, deer mice were found at high densities in spring, decreased by late summer, and were lowest during winter. The spring trapping period coincided with the peak of breeding for this species. Winter trapping occurred soon after a snowfall of 20–30 cm and daily temperatures were below 0°C. The combined effects of snow and cold may have discouraged or impeded the movement of deer mice, contributing to the low density observed.

In contrast, western harvest mice were found at higher densities during the winter in all treatments, and were found in fallow fields only in winter. In fact, 92% of all captures of this species occurred in winter. Other researchers have reported that peak captures of western harvest mice occur during winter, with fewest during the summer (Johnson and Gaines 1988, Foster and Gaines 1991). Trapping may underestimate the abundance of this species during spring and summer due to negative interactions between harvest mice and voles. The apparent increase in harvest mice in January may be influenced by the sharp decrease in vole density during that season. Data from other studies suggest a competitive interaction between these species when vole densities are high (Heske et al. 1984, Johnson and Gaines 1988, Foster and Gaines 1991). Harvest mice are known to avoid traps formerly occupied by voles (Foster and Gaines 1991). Further, small rodents, such as harvest mice, may have a greater physiological need to forage despite cold weather due to higher metabolic requirements (Clark et al. 1991). The meadow jumping mouse, a winter hibernator, was not caught in January, but was found at significantly higher densities in spring than late-summer in early-successional prairies ($P = 0.005$).

Plant and Small Mammal Diversity

Plant diversity was high (H' = 0.82) but small mammal diversity was low (H' = 0.30) in fallow fields. High plant diversity in these fields was due to the presence of both native and exotic species. However, the small mammal community in these fields was devoid of meadow jumping mice and house mice, and harvest mice were rare. The diversity of both plants (H' = 0.93) and mammals (H' = 0.74) was highest in the early-successional prairies and declined in established prairies, which had indexes of 0.39 and 0.59 for plants and mammals, respectively. Plant diversity was lower in established prairies primarily because species eveness declined as the prairie grasses began to dominate. Small mammal diversity declined in established prairies because meadow jumping mice did not utilize this habitat. There was a positive correlation (r = 0.66) between plant diversity and small mammal diversity in the six prairie sites. High plant diversity may increase the quality and diversity of food resources and attract a greater diversity of small

Table 1. Density (individuals/ha) and species composition of small mammals in three stages of prairie restoration in central Illinois. Standard errors are shown in parentheses.

Species	Fallow fields	Early-successional Prairies	Established Prairies
Deer mouse (*Peromyscus maniculatus*)	34.9 (5.6)	20.5 (3.3)	19.6 (3.1)
White-footed mouse (*Peromyscus leucopus*)	4.9 (1.0)	5.4 (2.9)	6.3 (0.6)
Meadow jumping mouse (*Zapus hudsonius*)	0.0 (na)	6.3 (3.4)	0.0 (na)
Western harvest mouse (*Reithrodontomys megalotis*)	1.8 (0.6)	3.4 (0.6)	5.5 (1.5)
Prairie vole (*Microtus ochrogaster*)	1.8 (0.4)	11.7 (2.7)	3.3 (0.5)
House mouse (*Mus musculus*)	0.0 (na)	1.0 (0.1)	4.1 (0.7)
Total	43.4 (7.6)	48.3 (13.0)	38.8 (6.4)

mammal species. Huntly and Inouye (1987) reported a positive correlation between plant diversity and small mammal diversity in an old field chronosequence.

Small mammal communities vary spatially and temporally in restored prairie systems. Early-successional prairies provide necessary habitat for meadow jumping mice and meadow voles. If restored prairies are allowed to succeed to large tracts dominated by dense stands of prairie grasses, certain mammal species (e.g. meadow jumping mice) may not compete successfully, resulting in lower beta-diversity. A management regime that includes prescribed burning and periodic light disking of patches within larger prairies could provide appropriate habitat for these species. Older established prairies provide better habitat for harvest mice, and support higher densities of small mammals during the critical winter months when populations of most species are lowest. Our data suggest that managing natural and restored prairies as a mosaic of successional communities may be the best method to retain a full complement of native small mammals.

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ECOLOGY OF FIRE IN SHORTGRASS PRAIRIE COMMUNITIES OF THE KIOWA NATIONAL GRASSLAND

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ABSTRACT: Although recurrent fires were historically prevalent natural components of grassland ecosystems, the incidence of fire in grasslands has greatly declined since the 1800s. This phenomenon is largely attributed to reduction of fuel from grazing by domestic livestock and active fire suppression. The use of prescribed fire has increased recently, primarily as a management tool to control invasion of woody plants into grasslands and to increase productivity of rangelands. Though there has been considerable descriptive research on the effects of wildfire on plant cover and productivity, the effects of prescribed burns on the shortgrass prairie ecosystem are not well known. Experimental research in the southern Great Plains on the Kiowa National Grassland in northeastern New Mexico, is an example of the kind of research needed to address the effects of season and frequency of fire in shortgrass prairie.

Key words: shortgrass steppe, experimental fire research, fire ecology, animal response to fire

INTRODUCTION

Environmental disturbance creates gaps in communities and allows recolonization of the gaps by individuals of the same or different species. Disturbance by fire plays a role in structuring most wildland plant communities, and the role of fire in community organization and development of grassland ecosystems is widely acknowledged (McPherson 1995). Grassland communities are likely to be differentially influenced by fire due to evolutionary adaptations to particular habitat features and conditions (e.g., precipitation patterns), the current physical and biological environment, and present and past land-use patterns.

Over a century ago, expansion of cultivated areas and removal of available fuel by livestock grazing contributed to post-settlement (i.e., post-1800s) decline in fire frequency, altered fire regimes, and extreme vegetation change in the Great Plains. Reliable historical records of fire frequencies in prairies of the southern Great Plains are not available because there are no trees to carry fire scars from which to estimate fire frequency. However, reconstruction of fire history via examination of charcoal fragments from lake sediment cores indicates that post-settlement patterns of charcoal deposition were highly variable but generally much lower than during presettlement intervals (Umbanhowar 1996). This suggests that settlement decreased the number of fires, and this parallels findings from historical accounts of desert grasslands (Bahre 1991).

In the absence of periodic fires, most grasslands give way to dominance by woody plants. Fire interacts with numerous other factors, including topography, soil, insects, herbivores (rodents, lagomorphs), and herbaceous plants to restrict woody plant establishment in grasslands (Grover and Musick 1990, McPherson 1995, Wright and Bailey 1982). Currently, there is general agreement that fire is necessary (though usually not sufficient) to control the abundance of woody plants and maintain most grasslands (McPherson 1995). The use of fire as a management tool has increased, but the question of how fire affects rangelands has not been fully addressed (McPherson 1995, Steuter and McPherson 1995). As a result, the extent and duration of fire's impact on grassland communities in the southern Great Plains is largely unknown.

NATURAL HISTORY

Southern Great Plains: Shortgrass Prairie

The southern Great Plains include the eastern third of New Mexico, the northern two-thirds of Texas, and most of Oklahoma. The region can be divided into shortgrass, mixed, and tallgrass prairies (Figure 1). Within the area, the shortgrass prairie lies west of the 100th meridian (Wright and Bailey 1982). It is estimated that less than 23% of true shortgrass prairie still exists in native vegetation (National Grasslands Management Review [NGMR] 1995). The grassland is semi-arid, with annual precipitation between 38 and 51 cm (15 and 20 inches).

Except for the sandy soils in southeastern New Mexico and the Canadian River country in northern Texas and western Oklahoma, soils are primarily clay loams, silt loams, and sandy loams. A caliche layer is frequently present at 51 to 91 cm (20 to 36 inches) in the fine-textured soils. Most of the area is tableland that is 1200 to 1829 m (4000 to 6000 ft) in elevation (south to north) on the western edge, and it slopes eastward to 915 m (3000 ft) on the edge of Llano Estacado in Texas. Dominant grasses are buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.) and blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.), with varying amounts of threeawns (*Aristida* spp. L.), lovegrass (*Eragrostis* spp. Beauv.), tridens (*Tridens* spp. Roem. and Schult.), sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), tobosagrass (*Hilaria mutica* (Buckl.) Benth.), galleta (*H. jamesii* (Torr.) Benth.), vine-mesquite (Panicum obtusum H.B.K.), bush muhly (*Muhlenbergia porteri* Scribn.), and Arizona cottontop (*Trichachne californica* (Benth.) Chase) (Bailey 1995, Wright and Bailey 1982).

Forbs can be abundant during wet years but they are seldom a major component of the shortgrass prairie. Common forbs include annual broomweed (*Xanthocephalum dracunculoides* DC.), false mesquite (*Hoffmanseggia densiflora* Benth.), western ragweed (*Ambrosia psilostachya* DC.), horsetail conyza (*Erigeron canadensis* L.), warty euphorbia (*Euphorbia spathulata* Lam.), silver-leaf night shade (*Solanum elaeagnifolium* Ca.), manystem evax (*Evax multicaulis* DC.), woolly plantago (*Plantago purshii* Roem. and Schult.), dozedaisy (*Aphanostephus* spp. DC.), goosefoot (*Chenopodium* spp. L.), croton (*Croton* spp. L.), summer cypress (*Kochia scoparia* L. Schrad.), and globemallow (*Sphaeralcea* spp. St. Hil.) (Wright and Bailey 1982).

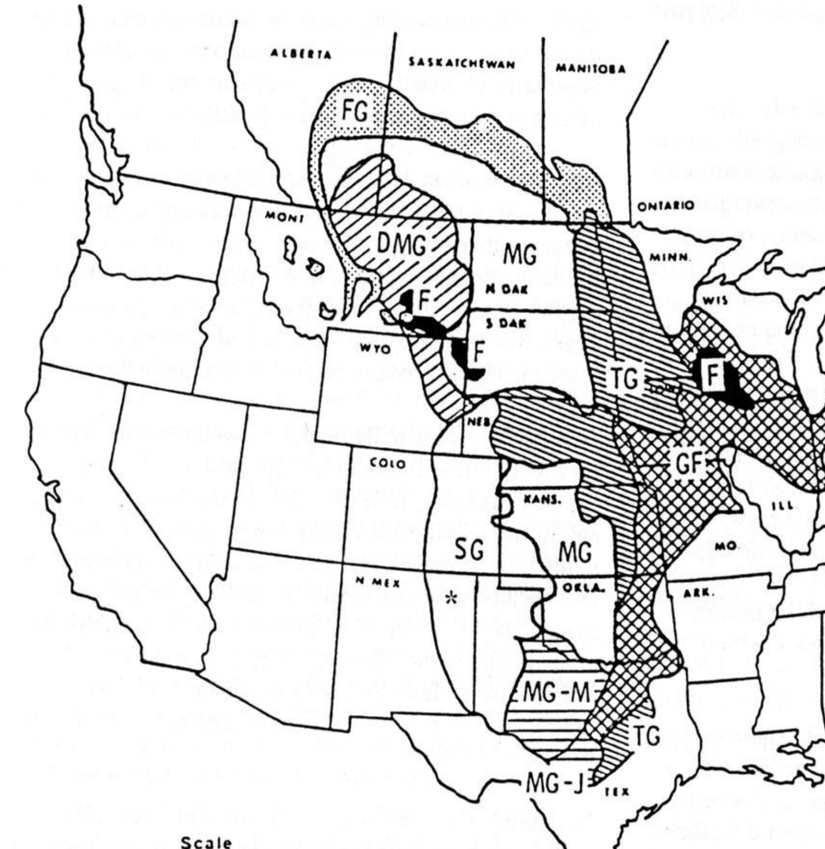

Figure 1. Natural vegetation of Great Plains grasslands (Wright and Bailey 1980). Modified from Kuchler (1965) and Rowe (1972). DMG = Dry mixed grassland; F = Forest; FG = Fescue grassland; GF = Grassland forest; MG = Mixed grassland; MG-J = Mixed grassland-juniper-oak; MG-M = Mixed grassland-mesquite; SG = shortgrassland; TG = Tall grassland; * Kiowa study site.

Dominant woody plants are honey mesquite, sand shinnery oak (*Quercus havardii* Rydb.), sand sagebrush (*Artemisia filifolia* Torr.), perennial broomweed (*Gutierrezia sarothrae* (Pursh) Britt. and Rusby), yucca (*Yucca* spp. L.), and fourwing saltbush (*Atriplex canescens* (Pursh.) Nutt.). Cactus (*Opuntia* spp. Miller) can also be abundant, particularly pricklypear (*Opuntia polyacantha* Haw.), brownspine pricklypear (*O. phaeacantha* Engelm.), walkingstick cholla (*O. arborescens* Engelm.), and tasajillo (*O. leptocaulis* DC.) (Wright and Bailey 1982).

Ecosystem Response to Fire

Considerable descriptive research (e.g., Launchbaugh 1964, Dwyer and Pieper 1967) was conducted to address fire effects on shortgrass prairie vegetation before 1980 (reviewed by Ford and McPherson 1996). These descriptive studies indicate that fire leads to decreased herbaceous production for one to three years, and herbaceous response is influenced strongly by precipitation. Fires also contribute to reductions in woody plant cover and increases in density and diversity of herbaceous dicots. In general, plant species in semi-arid grasslands are more strongly influenced by fire season and frequency than fire behavior (Steuter and McPherson 1995).

There is a lack of research that directly addresses the effects of fire on animal communities in shortgrasss prairie. Arthropods and mammals play important roles in ecosystem functioning of shortgrass prairie, serving as decomposers, pollinators, herbivores, predators, or prey. They cycle nutrients and form valuable links among trophic levels. Numerous studies in other ecosystems have indicated animal species, populations, and communities respond differentially to disturbance by fire, due in part to the fact that fire can have both direct and indirect effects. Direct effects are acute but ephemeral (i.e., fire-induced mortality). Indirect effects (i.e., alterations in habitat) are long-lasting and usually more important. Therefore, grassland fires may directly or indirectly elicit changes in population or community structure, and the magnitude of these changes depends on the vagility, life history and trophic level of the animal, and the timing, extent, and intensity of the fire (Ford and McPherson 1996).

Grassland burning elicits a diverse array of responses by arthropods. The degree of modification of arthropod populations by fire, the direction of change, and whether the effects are acute or chronic vary with several factors including fire characteristics, arthropod species, timing of the burn relative to phenological stage of arthropod development, influence of the fire on predator/prey and parasite/host ratios, post-burn weather, and the direction and degree of habitat restructuring. Responses of arthropods to season and frequency of fire also appear to vary between species (Warren et al. 1987).

The reaction of mammals to fire is a function of size and vagility. Most small mammals escape fires by hiding in burrows or rock crevices (Howard et al. 1959, Heinselman 1973). The most common cause of death for small mammals during fire is a combination of heat effects and asphyxiation. However, studies cited by Bendell (1974) indicate that soil provides insulation from fire for burrowing animals (Kramp et al. 1983). Other causes of death include physiological stress as mammals overexert themselves to escape, trampling as large mammals stampede, and predation as small mammals flee from fire (Kaufman et al. 1990).

Grassland fires that temporarily remove food and cover (litter and standing dead vegetation) may be detrimental to small rodents immediately after fire (Daubenmire 1968, Kaufman et al. 1990). However, repopulation of such areas is reported to be nearly complete within six months after the fire (Cook 1959). Mice and rodent populations often increase after fire in response to increased availability of forb seeds and insects (Lyon et al. 1978). In addition, burned areas often support more diverse animal populations than comparable unburned sites. This may be a result of habitat diversity (Beck and Vogl 1972, Wirtz 1977). Omnivores and carnivores are attracted to burns by increased plant diversity and associated small mammal populations (Gruell 1980). Levels of animal parasites are often lower in burned habitats (Bendell 1974).

Kaufman et al. (1990) suggest that most effects of fire on small mammals in grasslands are not neutral, but are instead either fire-positive or fire-negative. Fire-negative mammals include species that forage on invertebrates in the litter layer, species that live in relatively dense vegetation and eat plant foliage, and species that use, at least partially, aboveground nests of plant debris.

Fire-positive mammals include species that use ambulatory locomotion in microhabitats with a relatively open herbaceous layer, feed on seeds and/or insects, and use saltatorial locomotion (Kaufman et al. 1990). They exhibit an increase in populations and habitat use after fire because of an increased availability of forb seeds, insects, newly greening vegetation, the creation of open areas in otherwise dense habitat, and an eventual increase in forb cover. Increases may occur immediately or gradually as the areas begin to revegetate and habitat diversity increases.

No studies have focused on the issue of seasonal effects of fire on small mammals. Since most of the effects of season on population responses will undoubtedly be more subtle than general fire-negative and fire-positive responses, studies of differences in effects of grassland fires on small mammal populations will require intensive, replicated studies (Kaufman et al. 1990). Numerous studies have examined the response of small mammals in spring and autumn or spring and winter burn plots (Bock and Bock 1978, 1983; Bock et al. 1976; Tester and Marshall 1961); however these analyses focused on only the general effects of fire on small mammals, and no effects of season were evident (Kaufman et al. 1990).

Research

Ongoing research on the Kiowa National Grassland in northeastern New Mexico (Figure 1), uses a long-term (18 years) experimental framework to analyze the effects of season and frequency of fire on vegetation, small mammal, and arthropod communities in shortgrass prairie. Most previous research on the effects of fire in shortgrass prairie has not employed the experimental approach, but instead, has relied on study designs that are largely descriptive in nature.

Descriptive research is suitable for identifying patterns, but is considerably less useful for determining underlying mechanisms. This type of research has limited predictive power and, consequently, limited utility to managers (McPherson 1997, Weltzin and McPherson 1995). Manipulative field-based experimental research will help disentangle important driving variables because of strong correlations between factors under investigation (Gurevitch and Collins 1994). Identification of underlying mechanisms of change in community structure will enable researchers to predict community response to changes in fire or climate with a level of certainty useful to management (McPherson and Weltzin in press).

Preliminary analyses of short-term data from the Kiowa study have indicated that the shortgrass prairie ecosystem recovers relatively quickly from disturbance by fire. For example, vegetation cover and arthropod and mammal species richness on 2-ha experimental units treated with dormant-season fire recovered in approximately two months and did not significantly differ from untreated units. Some examples of research needs that can be addressed with long-term data from the Kiowa study are: the evaluation of the population responses of arthropods and mammals to prairie restoration using prescribed fire; identification of plant and animal species that are fire-dependent, neutral, or exhibit positive or negative responses to fire; evaluation of length of time after fire before positive or negative responses are produced; evaluation of the use of prescribed fire to benefit sensitive, threatened, or endangered plant and animal species; and determination of whether fire suppression or differences in season and frequency of prescribed burns will continue to contribute to population declines of some species (Ford and McPherson 1996).

CONCLUSIONS

The effects of fire on animal community structure in grasslands are related to trophic relationships and plant community structure. Conceivably, the effects of fire on arthropods will carry over to birds and small rodents that rely on arthropods as their prey base. This in turn will affect larger mammals and raptors. These relationships change rapidly as vegetation establishes and grows in recently-burned areas. Thus, community structure is likely to be temporally dynamic (Ford and McPherson 1996).

Change is the normal course of events for most ecological systems (Connell and Sousa 1983), and management of ecosystems is challenging in part because we seek to understand and manage areas that change (Christensen et al. 1996). Knowledge of plant and animal responses to fire timing and frequency may allow scientists and resource managers to predict the effects of prescribed burns on ecosystems.

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THE OUACHITA NATIONAL FORESTECOSYSTEM MANAGEMENT ADVISORY COMMITTEE: PROVIDING A FORUM FOR CONSTRUCTIVE DIALOGUE AMONG INTERESTS[1]

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ABSTRACT: The Ouachita National Forest Ecosystem Management Advisory Committee (AC) was established in 1990 by special legislation exempting it from the Federal Advisory Committee Act (FACA). Although originally intended as a technical advisory committee, its role has expanded to providing a forum for constructive dialogue among the USDA Forest Service and interest groups. This paper describes the events on the Ouachita National Forest leading to the formation of the AC, and explains how the AC functions. It then examines the role of the AC in providing a forum concerning ecosystem management. Fifty-seven individuals who have been involved in AC meetings were interviewed. Respondents included AC members, Forest Service personnel, and members of the public. A majority of the respondents thought that some of the most important results of the activities of the AC derived from the forum it has provided. The AC was viewed as neutral and unbiased. Respondents thought that conflict had declined, at least partially due to AC meetings. National forests with similar issues and stakeholders may find it beneficial to create a neutral and technical-based forum similar to the AC, even though this would involve compliance with the numerous provisions of FACA.

Key words: USDA Forest Service, Ouachita National Forest, advisory committee, conflict resolution, forum, Federal Advisory Committee Act

INTRODUCTION

Management of national forests is under much scrutiny with vigilant interest groups examining virtually every forest management decision. Better forest management decisions may be made and the number of appeals and lawsuits may be reduced by exploring alternative methods of communication. The New Perspectives program and subsequent ecosystem management approach of the USDA Forest Service have encouraged novel public participation strategies. The Forest Service launched New Perspectives in 1990 to bring a different way of thinking to managing the National Forest System, emphasizing ecological principles and research to improve ecosystem management (Salwasser 1991). Furthermore, it "seeks alternatives to solving problems by appeals, litigation, and legislation" (Salwasser 1991). In June 1992, the New Perspectives program was expanded to become ecosystem management, which was defined by Forest Service Chief Robertson as "an ecological approach ... to achieve the multiple-use management of the National Forests and Grasslands ... [blending] the needs of people and environmental values in such a way that the National Forests and Grasslands represent diverse, healthy, productive, and sustainable ecosystems" (Robertson 1992). The emphasis that New Perspectives and ecosystem management placed on alternative methods of collaborative decision making has been constrained by the provisions of the Federal Advisory Committee Act (FACA). FACA was designed to prevent private interests from controlling agency decision making and to eliminate wasteful spending of tax dollars on useless advisory committees. Unfortunately, it severely curtails the ability of federal agencies to use an advisory committee by listing many requirements for its establishment and maintenance (U.S. Department of Agriculture 1993).

This paper describes an alternative method of communication employed by the Ouachita National Forest (ONF), the Ecosystem Management Advisory Committee (AC). The events leading up to the formation of the AC are first discussed. This is followed by an explanation of the manner in which the AC functions, and the evolution of its role in providing a forum for constructive dialogue. The remainder of this paper focuses on some of the results of a comprehensive evaluation of the AC's accomplishments.

The Ouachita National Forest

As mandated by the Forest and Rangeland Renewable Resources Planning Act of 1974 and its amendment, known as the National Forest Management Act of 1976 (NFMA), the ONF in Arkansas and Oklahoma developed a comprehensive Land and Resource Management Plan that was finalized in 1986. As a result of fierce opposition to the plan's provisions regarding clearcutting and herbicide use, Forest Service Chief Robertson directed the ONF to engage in a supplemental planning effort in which issues raised in appeals were to be addressed (Holthoff 1993). The amended plan was published in 1990. According to a study by Voth et al. (1994), which summarized the results of Holthoff's survey of participants in the public involvement programs for both the initial and supplemental plans, a larger percentage of respondents was more satisfied with the supplemental plan than with the initial plan. Nevertheless, the controversy was not resolved. Administrative appeals were filed, followed by a lawsuit. Public opposition to the supplemental plan further intensified due to extensive coverage by Arkansas' two major newspapers, the Democrat and the Gazette, who were engaged in a circulation war.

The intense controversy surrounding the ONF's Land and Resource Management Plan led to the intervention by Forest Service Chief Robertson and U.S. Senator David Pryor (D - AR). The resulting meeting at the ONF in August 1990, known as the "walk in the woods," had several far-reaching consequences:—clearcutting would be eliminated in the ONF and the entire forest was designated as a "lead" forest in the New Perspectives program. In the ONF, New Perspectives program components were to include the following: showcase projects, ecosystem management research, and an advisory committee (AC).

The Advisory Committee

The creation and maintenance of the AC (then known as the New Perspectives Advisory Committee) was authorized by Congress through an appropriations bill rider introduced by Senator Dale Bumpers (D - AR) in 1990. The legislation specifically stated that the AC was exempt from the provisions of FACA. Through this exemption, the delays associated with meeting FACA's provisions were avoided. However, in most other aspects, the AC was similar to committees established under FACA.

Based on prior experience, ONF's Forest Supervisor, Mike Curran, insisted that the AC be composed of technical experts, rather than representatives of interest groups. However, interest groups were invited to nominate AC members in the fields of ecology, sociology, wildlife biology, landscape architecture, silviculture, recreation management, economics, hydrology, and soil science. Thirteen individuals were appointed officially to the AC by the Regional Forester.

The AC first met in May 1991 and has continued to meet approximately three times per year ever since. Most of the work of the AC is conducted during its meetings and consists of a discussion of agenda topics. The agenda is determined usually through the joint efforts of the Ecosystem Management Coordinator of the ONF and the chairman of the AC. Many of the issues on the agenda are suggested by the ONF and some are proposed by AC members. Furthermore, issues identified by the public as important increasingly have become part of the agenda. Several topics repeatedly have received attention during AC meetings. They include the Forest Service's "Desired Future Condition" concept, ecosystem management research at the ONF, a consideration of the social context of forest planning and management, and the allegation brought forth by some of the public that ONF management is biased in favor of planting and growing shortleaf and loblolly pine to the detriment of native hardwood species.

Through its discussions, the AC helps the ONF consider aspects of particular topics that would not have been considered otherwise or that would not have been considered in such depth. Concrete advice and recommendations are offered in some instances. These usually are mostly verbal and offered during AC meetings. On a few occasions, recommendations are provided in written form. Since the AC is advisory in nature, none of its findings are binding.

During meetings, the various agenda items are discussed. Commonly, Forest Service employees provide status reports and make presentations, after which AC members ask questions and discuss the topic at hand. After all AC members have had the opportunity to engage in the discussion, the audience is invited to join the discussions. AC meetings are always open to the public. Legal notice is given at least 30 days in advance in two statewide newspapers, and individuals who have demonstrated an interest in the past are notified by mail of upcoming AC meetings. Members of the public who have attended AC meetings include representatives of environmental organizations, trade organizations, other nonprofit organizations, the forest products industry, state agencies, individuals who hold private land within national forest boundaries, and individuals representing themselves. Furthermore, Forest Service personnel routinely attend AC meetings, including personnel from the ONF supervisor's office, the Southern Research Station, and occasionally ONF ranger districts.

Although the AC is technical in nature, over the years it has taken on the role of provider of a forum for discussion of forest issues. Members of the public, some of whom are distrustful of the Forest Service, have recognized AC meetings as an alternative venue in which to voice their concerns regarding forest management. The meetings have provided a setting in which the discussion about sometimes controversial issues does not become overly emotional, but rather allows arguments from various individuals, interest groups, and the Forest Service to be presented. Several factors have promoted this evolution. First, the meetings of the AC have always been open to the public and Forest Service personnel alike. Second, members of the audience have always had the opportunity to voice their opinions to the AC regarding the issues at hand. In some instances members of the audience have been invited to make formal presentations to the AC. Third, the AC has shown interest in the view points of members of the public in several ways. For instance, two field trips were organized by interest groups (an environmental organization and an organization representing the local timber industry) and one field trip was organized by an individual essentially representing his concerns about controlled burning and the misuse of fire. Fourth, the AC is perceived by the public as having influence on the ONF. Thus, interest groups that feel that the ONF does not take them seriously might try to make themselves heard indirectly by informing the AC of their concerns and points of view. And finally, the AC is perceived by the public and Forest Service employees to be impartial and highly professional due to its technical composition and the professional manner in which AC members have conducted themselves. Therefore, its findings are generally not disputed.

METHODS

Considered a success by most, the question arises how the AC's success came about, and whether it provides insights that may prove beneficial to other national forests. In order to assess the components and underlying factors of this success, 57 individuals who attended AC meetings at least twice were interviewed by phone. Sixteen respondents were current and former AC members, 23 respondents were Forest Service employees, and 18 respondents were members of the public. All interview questions were open-ended. With permission of the respondents, the telephone interviews were recorded and subsequently transcribed.

Interview data were analyzed on a question-by-question basis. For each question, individual responses were characterized using keywords or key sentences. Subsequently, responses labeled with the same keywords or sentences were grouped and tallied. Cross-tabulations were primarily carried out between answers to a particular question and the affiliation of the respondent (past or present AC member, Forest Service employee, member of the public).

Statistical analysis was limited to descriptive, rather than inferential statistics since the three groups of respondents could not be considered representative samples of three populations. Rather, the group of respondents consisted of the entire population of individuals who regularly attended AC meetings. Therefore, any findings were by definition true for this group (population) and inferential statistics would not have been appropriate.

RESULTS

Although the evaluation examined virtually all aspects of the AC, this paper only discusses the results pertaining to the AC's role in providing a forum for constructive dialogue. A full report on the results of the evaluation is provided by Frentz et al. (1997).

Most Important Role

All respondents were asked what they considered to be the most important role of the AC (Table 1). The most frequently reported role was to provide advice to the Forest Service, reported by 47% of all respondents. An almost equal number of respondents (42%) mentioned the AC's role in providing a forum. This role was commented on by a Forest Service employee who said, "And the ... role, I think that they have evolved into, is providing a respectable forum for policy debate for the public. ... People who have [a] strong interest in how the forest is managed and represent strong interests or agendas or constituencies often come to these meetings and they're given an opportunity to express their ideas or issues and they get listened to. And they sort of behave themselves because of the forum that this committee provides." Other important roles (not further discussed in this article) included the provision of an outside perspective (21%), representation of the public (11%), and a "search for the truth" (7%).

The evolution of the AC's role of providing a forum may have been advanced by its aura of impartiality. In order to determine whether respondents viewed the AC as unbiased, they were asked whether the AC took their interests into consideration (Table 2). Eighty-two percent of all respondents answered affirmatively. Furthermore, when respondents were asked whether all interests were taken into consideration equally, 63% agreed. Commonly used

Table 1. Function of the AC according to three groups of respondents (past and present AC members, Forest Service personnel, members of the public).

Role	Total* (N=57)	Past and Present AC Members (N=16)	Forest Service Personnel (N=23)	Members of the Public (N=18)
Provide advice to the Forest Service	27 (47%)	9 (56%)	12 (52%)	6 (33%)
Provide a forum	24 (42%)	9 (56%)	11 (48%)	4 (42%)
Provide outside perspective	12 (21%)	2 (13%)	7 (30%)	3 (17%)
Represent the public	6 (11%)	1 (6%)	2 (9%)	3 (17%)
Seek the truth	4 (7%)	1 (6%)	0	3 (17%)
Other	5 (9%)	5 (9%)	0	0

*Several respondents provided more than one answer. Therefore percentages add up to more than 100%.

Table 2. Percentage of respondents who thought that the AC considers the interests of the group to which the respondent belonged, and who thought that all interests were taken into consideration equally, respectively.

	Total (N=57)	Past and Present AC Members (N=16)	Forest Service Personnel (N=23)	Members of the Public (N=18)
Respondent's interests are considered	46 (81%)	14 (88%)	20 (87%)	12 (67%)
All interests are taken into consideration equally	36 (63%)	10 (63%)	5 (65%)	11 (61%)

adjectives describing the AC included "receptive," "balanced," "fair," and "broad-minded." However, a substantial minority (28%) did not think that the AC took all interests into consideration equally. Some respondents thought that the AC took the interests of certain "radical" interests (both environmental and timber) more into consideration. Others remarked that issues within the purview of certain professions received more attention than within the purview of other professions.

Three respondents pointed out that the AC could not possibly consider all interests, because of the multitude of interests. As expressed by an AC member: "I don't know what all interests are. ... And it [i.e., the AC] has no mechanism for having a comprehensive enough sense of what all the interests [are] to where it could see in confidence that it takes all interest into consideration equally. ... What it really then does take into consideration are those interests that end up being articulated before the Committee. And those are the interests as they're expressed through the existing organizations and organizational structures and personalities, who are committed to coming to meetings and to communicating with the Committee"

Most Important Result

All respondents were asked what they considered the most important results of AC activities so far (Table 3). The most frequently reported result by all three respondent groups was the moderation of conflict (56%). Many respondents described the forum that the AC provided as neutral and unbiased, the "honest broker," a conduit for the discussion among the ONF and its various interest groups. As a result, the dialogue in which the ONF, environmental interests, and timber interests engaged, became less antagonistic and more constructive.

*Many respondents provided more than one answer. Therefore, the sum of the percentages is greater than 100. Several members of the public did not know any results, or listed results that were mentioned by only one individual.
**Although 28% seems low, it was still the most frequently reported result by members of the public.

As an AC member put it, the controversy "moved away from gridlock to debate and discussion." A member of the public added that "this has resulted in a relatively civil interchange between opposing interests and individuals, which has been largely absent in Arkansas in natural resources and environmental affairs." Other important results of the AC (not discussed in this article) included its impact on ecosystem management (EM) research, its interpretation of EM, an increased diversity of viewpoints, the introduction of the social context in forest management considerations, and a statement regarding the desired future condition of the ONF.

The moderating effect of the AC on the amount of conflict was even more apparent when all respondents were asked directly whether the activities of the AC had led to a reduction in conflict between the Forest Service and interest groups (Table 4). Seventy-five percent of all respondents thought that AC activities had led, at least to some extent, to a reduction in conflict. Five respondents pointed out that the reduction in conflict may not have been solely due to the AC's activities. As explained by a Forest Service employee: "There's' definitely been a reduction in conflict. We can establish that. Now how do you tease out the different sources of that reduction? I tend to think that the major source was getting away from clearcutting. ... Bringing in research was another way to build credibility and reassure people that we're really looking at these relationships that people are concerned about. Now the Committee itself, I think, did contribute also by providing that sort of neutral third-party forum, in which people felt free to bring their ideas and concerns." The latter idea was echoed by a member of the public, who remarked, "They have provided citizens with a middleman, so to speak, ... , that makes people feel like they do have some kind of voice in how the forest is managed. And of course when they do provide input to the Advisory Committee, it is of course in the hopes that the Advisory Committee will take that information and use it to change the way the Forest is managed."

Respondents were also asked whether conflict between interest groups had been reduced as a result of AC activities (Table 5). Only 44% of all respondents answered affirmatively. The potential impact of the AC on the relationship among interest groups was elucidated by a Forest Service employee, who remarked that "the Committee meetings are rare occasions where, say, the

Table 3. Responses to the question "So far, what are the most important results of AC activities?" according to three groups of respondents (past and present AC members, Forest Service personnel, and members of the public).

Response	Total* (N=57)	Past and Present AC members (N=16)	Forest Service Personnel (N=23)	Members of the Public (N=18)
Moderation of conflict	32 (56%)	7 (44%)	20 (87%)	5 (28%)**
Impact on EM research	10 (18%)	2 (13%)	5 (22%)	3 (17%)
Interpretation of EM	7 (12%)	3 (19%)	3 (13%)	1 (6%)
Increased diversity of viewpoints	7 (12%)	3 (16%)	2 (9%)	2 (11%)
Introduction of social context	5 (9%)	3 (16%)	2 (9%)	0
Desired future condition statement	5 (9%)	3 (16%)	2 (9%)	0

*Many respondents provided more than one answer. Therefore, the sum of the percentages is greater than 100. Several members of the public did not know any results, or listed results that were mentioned by only one individual.
**Although 28% seems low, it was still the most frequently reported result by members of the public.

Table 4. Responses to the question "Have the activities of the AC led to a reduction in conflict between the USDA Forest Service and interest groups?" according to three groups of respondents (past and present AC members, Forest Service personnel, and members of the public).

Response	Total (N=57)	Past and Present AC members (N=16)	Forest Service Personnel (N=23)	Members of the Public (N=18)
Yes, at least to some extent	43 (75%)	12 (75%)	22 (96%)	9 (50%)
No	8 (14%)	0	0	8 (44%)
Don't know	6 (11%)	4 (25%)	1 (4%)	1 (6%)

Table 5. Responses to the question "Have the activities of the AC led to a reduction in conflict between interest groups?" according to three groups of respondents (past and present AC members, Forest Service personnel, and members of the public).

Response	Total (N=57)	Past and Present AC members (N=16)	Forest Service Personnel (N=23)	Members of the Public (N=18)
Yes, at least to some extent	25 (44%)	8 (50%)	14 (61%)	3 (17%)
No	19 (33%)	3 (19%)	3 (13%)	13 (72%)
Don't know/other	13 (23%)	5 (31%)	6 (26%)	2 (11%)

[environmentalists] and timber industry are thrown together. And they have shown some signs of being able to work together somewhat better. I think they realize that folks are human, that they're not monsters after all, and that they may even have a little bit in common now and then. I saw that going on tangentially. That probably did lead to some reduction in conflict, but the environmental litigant/appellant groups and the timber industry groups are still miles and miles apart, and probably always will be"

In order to explore the reduction in conflict between the Forest Service and interest groups, Forest Service employees were asked whether the Forest Service had increased its contact with the public as a result of the AC. Although 96% of interviewed Forest Service employees agreed that the ONF had improved its contact with the public, 35% brought up that the ONF already had a very good public involvement program: "The overall public involvement on this forest is by far the highest of any forest I've worked on. ... That [is] still part of the legacy of [retired forest supervisor] Mike Curran. ... He really opened up the forest to really getting the public involved in all of our processes. Not just from an information standpoint, but also from a decision making standpoint.... And that's really how this forest has survived all the controversy. ... The communication lines are always open, we don't shut them down." Whether the increase of contact with the public was due to ONF activities (such as changes in forest management practices and public involvement programs) or not, most respondents agreed that the AC had furthered additional contact.

Respondents differed in their opinions regarding the nature of the improved contact. Three (of 23) Forest Service employees pointed out that the number of interactions increased with people who were already involved, rather than an increase in contact with a wider audience. The latter opinion was supported by many members of the public. All but 1 of the 18 (94%) interviewed members of the public said that their willingness to engage in an active dialogue with the Forest Service had not changed as a result of AC meetings, indicating that they had always been involved with ONF issues. Three (of 23) Forest Service employees remarked that although the amount of contact with the public did not necessarily increase due to the AC's activities, the quality of that contact had improved by providing a different venue for interaction.

Success

The importance of the AC's role in providing a forum for constructive dialogue was further emphasized when all respondents were asked if they considered the AC a success. Ninety-three percent of all respondents thought that the AC had been a partial or a complete success (AC members: 94%; Forest Service employees: 100%; members of the public: 83%). When asked to justify why they considered the AC a success, the reason most frequently reported by all three respondent groups was that the AC provided a setting promoting dialogue between the Forest Service and interest groups. This was reported by 56% of all respondents, or 50% of AC members, 74% of Forest Service personnel, and 39% of the members of the public. According to a Forest Service employee: "It brought interests together in a better manner ... than before. And in a more structured manner. We just couldn't do it. We had various meetings, we had open houses, we had forums, all encompassed within the planning process, which is a constraint in itself. And to have an ongoing process, where everyone knows that perhaps on a quarterly basis there will be an opportunity ... to come forward ..., it was a success beyond my wildest dreams."

In order to further explore the success of the AC, respondents were also asked which factors had facilitated this success. Table 6 provides an overview of the most frequently reported factors. The AC's composition, consisting mostly of technical experts, was reported most frequently as a facilitating factor, especially by employees of the Forest Service. The role of the Forest Service was also mentioned frequently, especially by AC members. The Forest Service facilitated the AC's success through assistance in logistics and the positive attitudes and commitment of Forest Service employees. The relationship between the AC and members of the public was also considered an important contributor to the AC's success, especially by members of the public. Other facilitating factors were the leadership provided by the AC's chairmen (12%, n=57) and the social interactions among the AC members, Forest Service employees, and members of the public (9%).

The factors contributing to success were related to the AC's role in providing a forum for dialogue. For instance, the technical nature of the composition of the AC resulted in the perception that the AC was unbiased and highly credible, having the respect of members of the public and Forest Service employees alike. This was reflected in the positive relationship of the AC with the Forest Service and members of the public. As explained by an AC member, "The committee has been very open. The committee has not been a very egotistical group that was only interested in their own pontification, but [it] is really understood that their role was to encourage the dialogue, and to some extent ... [the committee] use[s] [their] expertise to make judgments about what people say."

Respondents were also asked which factors have impeded the success of the AC. Table 7 provides an overview of the most frequently reported factors. The table shows that almost 25% of the respondents did not think that there had been any obstacles to success. Furthermore, if respondents did identify obstacles, they often pointed out that these were only minor. The most commonly reported

Table 6. Most frequently reported factors facilitating the success of the AC according to three groups of respondents (past and present AC members, Forest Service personnel, and members of the public).

Response	Total (N=57)*	Past and Present AC members (N=16)	Forest Service Personnel (N=23)	Members of the Public (N=18)
AC's composition	32 (56%)	8 (50%)	19 (83%)	5 (28%)
Role of Forest Service	19 (33%)	10 (63%)	7 (30%)	2 (11%)
Relationship between AC and members of the public	13 (23%)	2 (13%)	2 (9%)	9 (50%)
Leadership provided by AC chairmen	7 (12%)	2 (13%)	2 (7%)	3 (17%)
Social interactions	5 (9%)	2 (13%)	3 (13%)	0

*Percentages add up to more than 100% since many respondents reported more than one facilitating factor.

Table 7. Most frequently reported factors impeding the success of the AC according to three groups of respondents (past and present AC members, Forest Service personnel, and members of the public).

Response	Total (N=57)*	Past and Present AC members (N=16)	Forest Service Personnel (N=23)	Members of the Public (N=18)
Meeting frequency too low	16 (28%)	9 (56%)	5 (22%)	2 (11%)
There were no impeding factors	13 (23%)	1 (6%)	7 (30%)	5 (28%)
AC's composition	10 (18%)	5 (31%)	3 (13%)	2 (11%)
Relationship between AC and members of the public	10 (18%)	4 (25%)	2 (9%)	4 (25%)
Role of Forest Service	7 (12%)	0	0	7 (39%)
Membership turnover	7 (12%)	2 (13%)	3 (13%)	2 (11%)
Getting started took time	4 (7%)	3 (19%)	1 (4%)	0
Focus not always appropriate	4 (7%)	0	3 (13%)	1 (6%)

*Percentages add up to more than 100% since many respondents reported more than one facilitating factor.

factor was that the meeting frequency of approximately three meetings per year was too low. The second most commonly mentioned obstacle was AC composition. Although a majority of the respondents had identified the composition of the AC as a factor facilitating success, almost a fifth of the respondents considered the composition to be an impediment. Several respondents pointed out that the AC, consisting mostly of academics, could be viewed as an elite group, which could impede its success. Some respondents commented on the drawbacks of allowing the public to participate as much as it does, remarking that it sometimes slowed the discussion down by having special interest groups continually presenting their viewpoints. According to an AC member, "many times it almost appeared as a free for all. That it wasn't just the committee hearing presentations and deliberating amongst themselves. It was the whole audience, with the committee, going about commenting and back and forth. This in some ways added things to the committee's knowledge and some ways may have been old stuff being rehashed again, when you have special interest groups continually presenting their viewpoints on things. And so it was probably that which led the committee to evolve into a public forum thing which is somewhat of a positive. It made for additional dialogue. On the other hand, being open and not controlled in the meeting set up meant sometimes that the committee was waiting for these other people to have their say ... and sometimes did not necessarily contribute to the discussion." In contrast, several members of the public thought that the role of the Forest Service was too large. They remarked that the Forest Service had tried too much to influence the AC and was too controlling. Obviously, the impeding factors focusing on committee composition, the relationship with the public, and the role of the Forest Service were related to the AC's role as provider of a forum. Other impeding factors included membership turnover (12%), the time it took to get the AC started (7%), and an occasionally inappropriate focus of the discussions (7%).

DISCUSSION

Originally set up as a technical advisory committee, the AC took on the additional role as a provider of a forum for dialogue among the ONF and members of the public. According to respondents, this became its second most important role. Furthermore, the AC was considered successful by most respondents because of its role in the reduction of conflict among the ONF and members of the public.

Although the percentage of members of the public who commented positively on the AC as a provider of a forum for dialogue was generally lower than the percentage of AC members or Forest Service personnel, in several instances it was still the most common response to a particular question among the members of the public. Nevertheless, the lower percentage of members of the public who commented positively on this role of the AC could suggest that the decrease in conflict with the ONF (as implied by the decline in the number of appeals and the absence of lawsuits) was not as much a result of AC activities as AC members and Forest Service personnel think. However, given the repeated emphasis by members of all respondent groups on the importance of the forum that the AC provides, it is reasonable to assume that the AC has at least contributed to the decline in conflict.

The composition of the AC has contributed significantly to the success of the forum it has provided. The members of the AC are primarily technical experts drawn from universities and a few agencies. They do not represent interest groups, nor have they taken any public stance on issues concerning the ONF. As a result, all parties with an interest in forest management at the ONF (Forest Service, timber interests, environmental interests, others) have been able to agree about the integrity of members of the AC and the quality of the input provided by the AC. Furthermore, the AC is not threatening to any of the involved parties. Forest Service employees, environmentalists, and timber industry representatives alike feel that the AC takes their statements seriously. Furthermore, because of the technical nature of the AC, agenda items tend to be of a technical, rather than an emotionally charged nature. Although charged subjects are touched upon while discussing technical issues, the discussion usually remains detached from emotion. However, in a few instances, the AC has explored the technical basis of some of the emotionally charged issues in an effort to improve the AC's understanding of these issues.

Recommendations for Other National Forests

National forests and other public lands facing similar issues and controversies as the ONF may want to consider the establishment of an AC, if only to help provide their managers with a fresh outside perspective. The cost of establishing such a committee may be negligible when compared to the cost of one lawsuit that an AC may help prevent.

Where issues have become very polarized, an AC should be made up of technical experts rather than representatives of interest groups. Meetings of a committee comprised of interest group representatives could easily turn into shouting matches and end up in stalemates. A technical AC, composed of local or regional experts, could command respect from a variety of interest groups, including the Forest Service. The propensity of Forest Service personnel to regard technical expertise highly should facilitate the interaction between the Forest Service and the AC. Once the amount of conflict has been reduced, and trust and respect has been increased among stakeholders and between stakeholders and the Forest Service, a gradual change in composition to include stakeholders may be appropriate. However, "fringe" groups should not be allowed to dominate. National forests interested in establishing an AC could identify prospective AC members using the same successful process that was used by the ONF. Members of the public that had previously been involved in forest management issues were asked to nominate experts in a variety of fields for assignment to the AC. Thus, although members of the public were not invited to become AC members, they were involved in deciding upon the composition of the AC.

Any national forest establishing an AC needs to be highly committed to the committee for it to be successful. Strong commitment and support from the Forest Supervisor is an absolute requirement. The national forest should further provide logistic support, preferably by someone permanently assigned as the liaison with the AC. It is important that the national forest provides the AC with information and keeps AC members interested. Also, it is beneficial to make AC meetings enjoyable through overnight stays and field trips. At the same time the national forest should allow the AC the freedom to take up any issues it wishes. It should be clear to all involved, that the AC is not a "kept" committee. The AC should not function as a watch dog either.

The major hurdle to establishing an AC for federal lands is the Federal Advisory Committee Act (FACA) of 1972. Although many have questioned whether the FACA is still useful and even have suggested changes to the Act (Wondolleck and Yaffee 1994), FACA is still in place and must be accommodated. A consideration of the host of Forest Service memoranda regarding FACA shows clearly that any AC similar to the one at the ONF would be considered a Federal Advisory Committee and thus be subject to FACA's provisions. Individual national forests wanting to establish an Advisory Committee have three choices: 1) Obtain an exemption from FACA through legislation, as was the case for the ONF AC; 2.) Comply with FACA and endure FACA's abundant red tape (e.g., FBI background checks of all prospective AC members); or, 3.) Ignore FACA and hope that nobody notices (which, of course, creates the potential for lawsuits and the invalidation of achievements by the AC). The second option may be the most straightforward. The effort needed to deal with FACA requirements will more than likely pay off through the successful establishment of an AC.

The Ouachita National Forest Ecosystem Management Advisory Committee has been very successful. A majority of the individuals involved, whether they are AC members, Forest Service personnel, or members of the public, have benefited from AC meetings. With hard work from all parties involved, it should be possible and very much worthwhile to replicate this success story on other national forests across the U.S.

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THE HISTORICAL AND PRESENT EXTENT AND FLORISTIC COMPOSITION OF PRAIRIE AND SAVANNA VEGETATION IN THE VICINITY OF HAMILTON, ONTARIO

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ABSTRACT: Historical and recent information on prairie and savanna communities in the vicinity of Hamilton, Ontario, located at the western end of Lake Ontario, was collected and synthesized to compare their past and present extent and floristic composition. This comparison provides the technical justification for the development of a conservation strategy for local prairie and savanna vegetation. Sources of historical data included the original land surveys (ca. 1793-1832), the diary of Lady John Graves Simcoe (ca. 1796) and early plant lists (1862, 1874, 1897). The areas referred to variously as "oak plains", "open plains" and "plains" by the original surveyors were part of a mosaic of prairie, oak savanna, and woodlands dominated by *Quercus alba, Q. ellipsoidalis, Q. macrocarpa, Q. velutina, Castanea dentata,* and *Pinus strobus*. Based on the historical evidence and more recent soil surveys and floristic work, it is estimated that prairie and savanna vegetation covered at least 3800 ha around the time of settlement (ca. 1790-1830), but a more realistic figure is 5000 to 6000 ha. These dry, sandy, open areas were dominated by prairie grasses, especially *Sorghastrum nutans*, and they supported many other species characteristic of prairies and savannas. Edaphic factors and fire were likely responsible for the maintenance of these open communities. Presently, only a single high-quality and representative prairie remnant covering 0.5 ha is known from the Hamilton area, along with several other more disturbed remnants. Far less than 1% of the original prairie and savanna vegetation in the vicinity remains. These remnants represent a globally and provincially rare community type, which support a number of species considered rare both locally and in Ontario. These sites are conservation priorities, urgently needing the development of a strategy for their conservation and management.

Key words: prairie, savanna, historical and present extent and composition, Hamilton, Ontario, Canada

INTRODUCTION

Prairie and savanna vegetation (after Curtis 1959) formerly occurred discontinuously across much of southern Ontario (Bakowsky and Riley 1994, Gore and Storrie Limited 1993). In southern Ontario, these communities occurred along sandy nearshore areas of the Great Lakes interior sand plains, south-facing sandy slopes, gravelly moraines, and sandy kame moraines. Where these physiographic features are associated with rivers, this vegetation was especially prominent (Gore and Storrie 1993). In Ontario's Southern Deciduous Forest Region (Carolinian zone), prairie and savanna vegetation occurred at locations along the Detroit, St. Clair, Thames, and Grand rivers, on dunes along the shores of Lakes Erie, Huron, and Ontario; inland on the Norfolk Sand Plain and the Horseshoe and Paris Moraines; and at the western end of Lake Ontario (Wood 1961, Pratt 1979, Langendoen and Maycock 1983, Faber-Langendoen 1984, Faber-Langendoen and Maycock 1987, House and Carleton 1988, Varga 1989, Szeicz and MacDonald 1991, Bakowsky and Riley 1994). To the north and east of the Carolinian zone, prairie vegetation has also been documented in the vicinity of Lake Simcoe (Reznicek 1980, 1983; Reznicek and Maycock 1983), on the south side of Rice Lake (Catling et al. 1992) and along the Trent River (Catling and Catling 1993). The remaining prairie and savanna vegetation in southern Ontario has been the subject of a review and assessment commissioned by the Ontario Ministry of Natural Resources (Gore and Storrie Limited 1993, Bakowsky and Riley 1994). Prairie and savanna remnants occurring in south-central Ontario are mapped on Figure 1.

A number of hypotheses have been developed to explain the occurrence of prairie and savanna vegetation, including anthropogenic (Day 1953, Curtis 1959, Dorney and Dorney 1989), climatic (Deevey and Flint 1957, Szeicz and MacDonald 1991) and edaphic factors. It has been suggested by a number of researchers in southern Ontario that all three are closely related and likely responsible for the origin and continued persistence of this vegetation in Ontario (Rogers 1966; Reznicek 1983, Reznicek and Maycock 1983, Faber-Langendoen 1984, Bakowsky 1988, Catling et al. 1992, Gore and Storrie Limited 1993).

In the vicinity of the city of Hamilton, at the extreme western end or "head" of Lake Ontario (Figure 1), prairie and savanna vegetation was described by Lady John Graves Simcoe (1796), Gourlay (1822) and Kernighan (1875), as well as the original land surveyors. The plant lists compiled by early botanists for the area document a flora rich in prairie species, many of which are no longer known from the region (Craigie and Craigie 1854, Logie 1862, Buchan 1874, Dickson and Alexander 1897, Dickson 1905). Since the 1950s, a number of prairie plant species have been discovered or rediscovered in the region (Pringle 1969, Goodban 1995). Several tiny prairie remnants, along with related communities, such as oak woodland and cliff rim woodland, are presently known from this vicinity (Heagy 1993; Riley et al. 1996, Goodban 1996). Elsewhere in the region, clusters of prairie plant species occur in more disturbed areas (Axon 1989, Heagy 1993, Goodban 1996). Passing reference to the historical occurrence of prairie and savanna near Hamilton has been made by MacDonald (1987) and Bakowsky (1994). In the present study, historical and recent information on prairie and savanna communities in the vicinity of Hamilton, Ontario, was collected and synthesized. This work was completed in order to:

1) compare the presettlement and present extent and floristic composition of prairie and savanna vegetation in the region;

(2) provide the technical justification for the development of a conservation strategy for prairie and related vegetation in the Regional Municipality of Hamilton-Wentworth; and,

3) to contribute to an understanding of the natural vegetation patterns of the southern Great Lakes region.

METHODS

Original land surveys for the townships in the vicinity of Hamilton (Ancaster, Barton, Beverly, West Flamborough, East Flamborough) were checked at the Ontario Ministry of Natural Resources, Information Branch, Survey Records Section, for reference to plains and other unforested areas. The Wentworth and Halton soil surveys (Presant et al. 1965, Gillespie et al. 1971), geological (Ontario Geological Survey - Maps 2508, 2509 and 2240 - quaternary geology), and topographic maps (Energy, Mines and Resources Canada 30M/4, 30M/5, 40P/1, 40P/8, 1:50 000) were used to identify the likely extent of prairie and savanna in the region. Publications and diaries of early travellers (Lady Simcoe 1796, Gourlay 1822), settlers (Kernighan 1875) and botanists (Craigie and Craigie 1854, Logie 1862, Buchan 1874, Dickson and Alexander 1897, Dickson 1905) were reviewed for references to "plains" and prairie plant species. Recent studies and reports that refer to prairie or related vegetation in the vicinity of Hamilton were reviewed (Pringle 1969, House and Carleton 1988, Axon 1989, Heagy 1993, Goodban 1995, Riley et al. 1996, Goodban 1996). A list of plant species known to have prairie and savanna affinities in southern Ontario was synthesized from Bakowsky (pers. comm.), Riley (1989), and Gore and Storrie Limited (1993), and was subsequently used to check historical and recent plant lists from the Hamilton area. Nomenclature largely follows Morton and Venn (1990) and acronyms for herbaria follow Holmgren et al. (1981).

Regional Context

The City of Hamilton and environs are located at the extreme western end of Lake Ontario, in the Regional Municipality of Hamilton-Wentworth. The major landscape features in this area that contain sandy or gravelly substrates and that may have supported prairie and savanna vegetation are shown on Figure 2 and briefly discussed below.

The Dundas Valley is a major re-entrant valley in the Niagara Escarpment. It is a prominent feature with topography varying from dissected kame terrain in the upper western end of the valley, where the escarpment is buried, to drowned stream valley and lagoon terrain

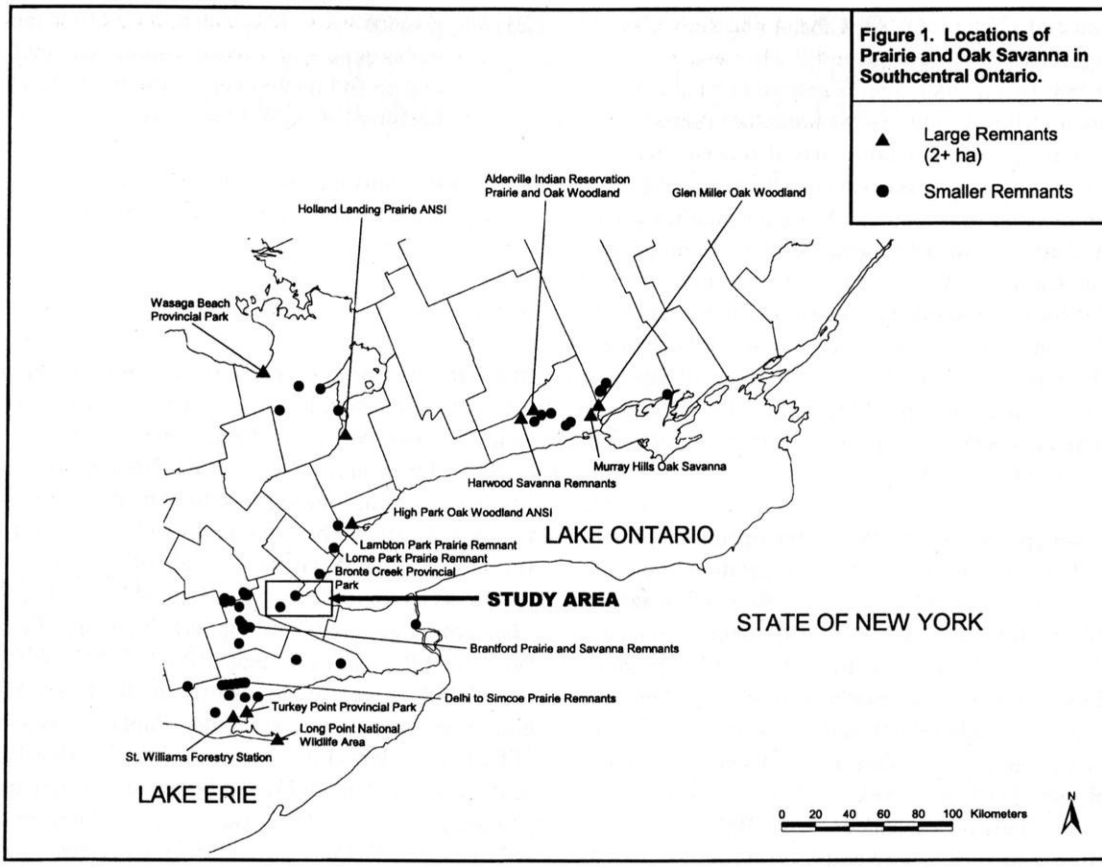

Figure 1. Locations of Prairie and Oak Savanna in Southcentral Ontario.

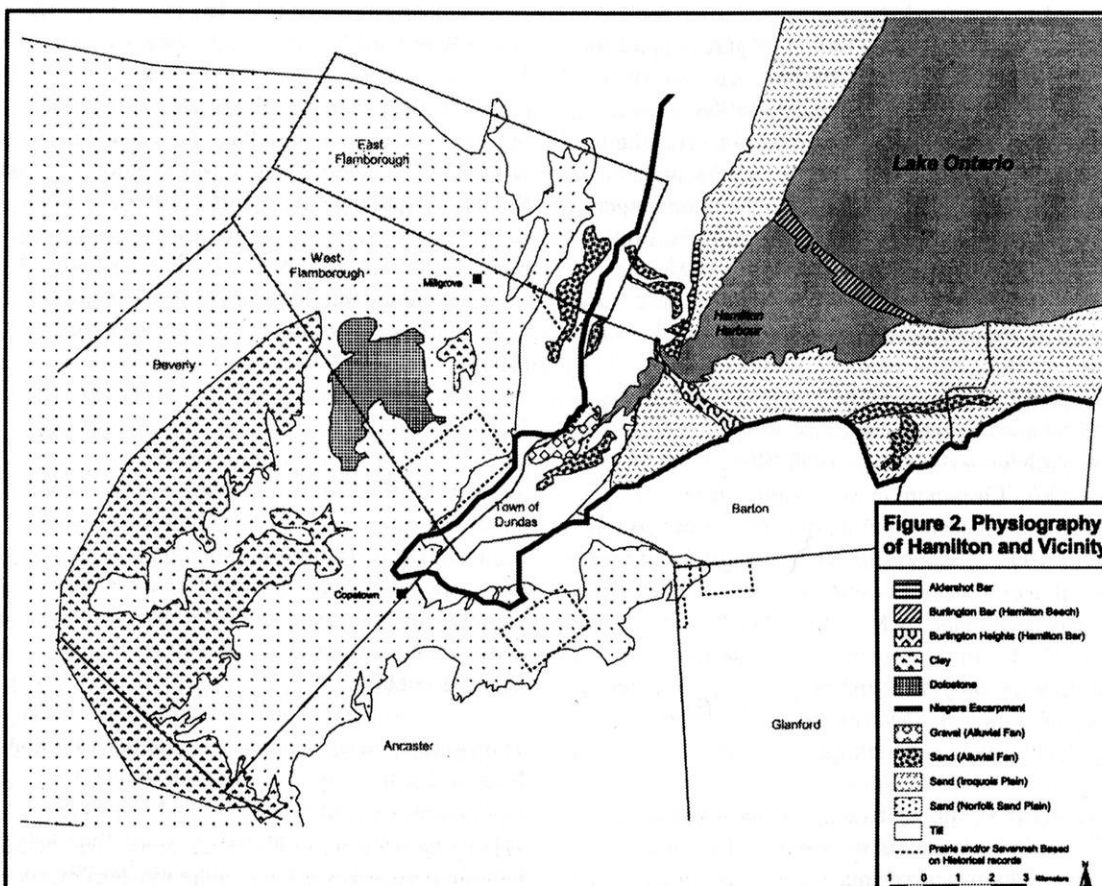

Figure 2. Physiography of Hamilton and Vicinity

towards the east (Heagy 1995). The lagoon, known as Cootes Paradise, has formed behind the Hamilton Bar or Burlington Heights, which is a 35-m high barrier beach bar created by Lake Iroquois. The Aldershot Bar is a similar but now landlocked feature located between the escarpment and Hamilton Harbour. Both the Hamilton and Aldershot bars are capped with cemented gravel, with underlying stratified layers of sand and silty sand.

Other Lake Iroquois shoreline features in the form of low erosional bluffs and small sand bars occur some 3.0 km inland from Lake Ontario in Burlington, in the Regional Municipality of Halton (Karrow 1987). To the east of the Hamilton Bar is Hamilton Harbour or Burlington Bay, which is separated from the open waters of Lake Ontario by the active, sandy barrier beach known as the Burlington Bar or Hamilton Beach Strip (Heagy 1995).

Surrounding much of the Dundas Valley is the northeastern lobe of the Norfolk Sand Plain (Chapman and Putnam 1984, Heagy 1995). There are also alluvial fans comprised of sand over gravel at Dundas and Copetown (Karrow 1987, Heagy 1995). Sandy soils also predominate on the Iroquois Plain between the Niagara Escarpment and Lake Ontario (Presant et al. 1965, Gillespie et al. 1971, Karrow 1987). Elsewhere in Hamilton-Wentworth, the landscape is comprised predominantly of dolostone, clay, and till plains (Karrow 1987).

Early Descriptions

A review of early historical accounts of the greater Hamilton area provide several clues to the presence of prairie and savanna communities around the time of settlement. Sources of historical data include original land surveys (1793–1799), the diary of Lady John Graves Simcoe, a questionnaire of inhabitants by Gourlay (1822), the accounts of an early settler, Kernighan (1875), and early botanical surveys.

Original Land Surveys

Early land surveys completed by Jones (1793 - 1799), Grant (1794), Stegman (1797, 1799), and Black (1832) for Flamborough, Ancaster, Beverly, and Glanford Townships, make frequent reference to "plains," "open plains," "black and white oak plains," "small pine and oak plains," and "open woods - oak, chestnut, pine." In some instances, there is no reference made in the survey notes to the presence of timber over an area of several concession lots. The accounts of the early land surveyors would suggest that prairie and savanna were quite widespread in the greater Hamilton area.

Diary Of Lady John Graves Simcoe (1792–1796)

Lady John Graves Simcoe was the wife of the First Lieutenant-Governor of the Province of Upper Canada. During her stay in Upper Canada, Lady Simcoe kept a diary of her countryside travels, which included pen and pencil sketches of the landscape. The diary provides several indications that at the time of settlement, the site of present day Hamilton contained broad expanses of prairie and savanna.

Lady Simcoe travelled to the head of Lake Ontario from Niagara-on-the-Lake in early June of 1796. While crossing what is now Hamilton's east end, after descending the escarpment and travelling through several miles of swampy ground, Lady Simcoe noted that:

> ...we came into good galloping ground
> on fine turf by the side of the lake, till
> we came to the King's Head Inn at the
> Head of the Lake.

The King's Head Inn was commissioned by Lieutenant-Governor Simcoe to provide accommodation for travellers moving between Niagara and La Tranche (London). The inn was located at the south end of a long beach strip that runs between modern day Hamilton and Burlington. Lady Simcoe described the view from the King's Head Inn as follows:

> From the rooms to the N.W. we see
> Flamborough Head and Burlington Bay.
> The sand cliffs on the north shore of
> Burlington Bay look like red rocks. The
> beach is like a park covered with large,
> spreading oaks.

A topographical description of Upper Canada (Robertson 1934) also makes reference to the area between Lake Ontario and Burlington Bay as a "...long beach, of about five miles, from where there is an outlet to Lake Ontario..." During her stay at the King's Head Inn, Lady Simcoe made several sketches in her diary of the Burlington Bay area that depict an open landscape characterized by the presence of widely scattered large trees.

At the western end of Burlington Bay is a height of land, referred to as the Burlington Heights or Hamilton Bar, that separates the bay from Cootes Paradise. Richard Beasley was an Indian trader who was the first settler at the "Head of the Lake." At that time, Beasley owned the heights, which are presently occupied by Dundurn Park and the Hamilton Cemetery. On a trip to visit the Beasley household, Lady Simcoe noted that the point of land separating Burlington Bay from Coote's Paradise "...is quite like a park, with large oak trees dispersed, but no underwood."

During her stay at the Beasley House, Lady Simcoe had an opportunity to further explore the Burlington Heights area and do some sketching. In her diary, she notes:

> ...we walked two miles on this park, which is quite natural, for there are no settlements near it....the country appears more fit for the reception of inhabitants than any part of the province I have seen, being already cleared. The Governor says the country on the banks of the La Tranche (Thames River and Lake St. Clair) is like this, but the plains are infinitely more extensive.

The area that Governor Simcoe is comparing Hamilton to is the modern day City of London, Ontario, which Lady Simcoe previously notes the Governor as describing as "...a fine, dry plain without underwood, but abounding in good oak trees."

During a stroll on the Burlington Bay beach, Lady Simcoe reports that:

> ...Beasley gave me a weed, somewhat like a milkwort, a small white flower with a long root, which tastes hot and aromatic, which he called rattlesnake plantain. I think it is what Charlevoix calls senega.

Senega snakeroot (*Polygala senega*) is a prairie species that can still be found in the vicinity of Hamilton.

After returning to the King's Head Inn from her visit to the Beasley House, Lady Simcoe went for a horseback ride along the beach that separates Burlington Bay from Lake Ontario. Upon seeing an Indian encampment she noted that "...their huts and dogs among the fine oak trees they were under, formed a picturesque appearance."

In summary, Mrs. Simcoe's diary accounts of open, parklike areas with large oak trees, no underwood, and fine turf suggest that prairie and oak savanna vegetation was fairly widespread around the perimeter of the western end of Lake Ontario.

Statistical Account of Upper Canada with a view to a Grand System of Emigration - Gourlay (1822)

An extensive survey of the human and physical resources of Upper Canada was completed by Robert Gourlay in 1817. The inhabitants of each township in Upper Canada were asked to respond to several questions which included requests for information on the types and abundance of trees present. The answers provided to Gourlay allowed him to provide a general description of the forest communities present in southwestern Ontario during the early phases of settlement. Gourlay (1822) reports:

> In 1784, the whole country was one continued forest. Some plains on the borders of Lake Erie, at the head of Lake Ontario, and in a few other places, were thinly wooded: but, in general, the land in its natural state was heavily loaded with trees; and after the clearing of more than 30 years, many wide-spread forests still defy the settler's axe.

The report returned to Gourlay for the Township of Ancaster states: "...The face of the township is pleasantly diversified with hill and dale, with some plains."

This account of thinly wooded plains at the western end of Lake Ontario is consistent with the observations of Lady John Graves Simcoe during her travels to the King's Head Inn and Burlington Heights and the account of Kernighan (1875) that follows.

History of the City of Hamilton - Kernighan (1875)

Further clues to the presence of prairie vegetation around the western end of Lake Ontario are provided in Kernighan's historical account of the City of Hamilton published in 1875. Kernighan, one of the early prominent citizens of Hamilton, notes that:

> The site of Hamilton was originally covered with a dense growth of tall, rank, Indian grass, with a coarse serrated edge, which, when drawn the reverse way across the hand, cut like a sharp saw. The country between the mountain and the bay was cut here and there with deep ravines and dotted with patches of swamp or swale - a favourite haunt of quails, rattlesnakes and frogs. The monotony of the Indian grass was relieved here and there by a tall water elm, and close, low, and almost impenetrable patches of shrubbery which formed a safe shelter for the wolves. On the spot now occupied by the market square was a particularly dense growth of this shrubbery, which was the rendezvous of the wolves for miles around...
>
> ...There were serious drawbacks to the cultivation of the valley. The Indian grass already mentioned is very hard to exterminate. The roots are numerous, long and fibrous, making the sod very tough and almost impenetrable to a plow-share.

The area that Kernighan is referring to is the portion of the Iroquois Plain located between the base of the Niagara Escarpment northward to the shore of Burlington Bay.

Extent of Prairie and Savanna in Hamilton and Vicinity

Original land surveys

Although portions of the Regional Muncipality of Hamilton-Wentworth (formerly Wentworth County) are lacking original survey records, relatively detailed field notes exist for most of the area. Notable exceptions are parts of Ancaster Township and all of Barton Township (now the City of Hamilton), for which no survey notes are available. Areas described as "plains" by the original surveyors are shown on Figure 3.

In June of 1793, Augustus Jones surveyed the lots in "the new Townships Beverly and Ancaster" proceeding "down the line running from Burlington Bay to the River la Tranche" (Thames River) through the lands "assigned to the Six Nations of Indians." Along the southern limits of Beverly Township's first concession, Jones noted only "small pine and oak" for timber between lots 27 and 35. At lot 36, he mentioned "a white oak tree" marked as a reference point. Along the southern limits of West Flamborough Township's first concession, no reference is made to timber between lots 2 (oak chestnut) and 14 (oak and small pine). Lot 15 was "Widow Morden's place" and lot 16 was "Morden's field." Part of lot 16 and all of lots 17 through 19 were "open plains - sandy soil."

In December of 1793, Jones described part of the area between lots 25 and 26 in West Flamborough's second concession as "plains." He then went on to survey the boundary of the Township of Glanford early in 1794. Along the boundary with Ancaster Township, on the first concession, he noted "plains - small oaks and then pine." Soon after he described the same area in lot 1 as "plains...small brush and pine," lot 2 as "timber small pine and oak, thick of underbrush," lot 3 as "open plains," lot 4 as "open plains - Jacob Smith settled and improved," lot 5 as "a road from Burlington Bay to the Grand River [modern day Highway 6] - plains," lot 6 as "plains to 23 chains," lot 7 as "oak and pine scrubby - thick of small bushes," and lot 8 "pine, some oak, the greatest part has been killed by the fire, underbrush thick." In January of 1794, Jones again described the area in the vicinity of Morden's Field (ie. Concession I, Lot 16, West Flamborough) as "plains."

Lewis Grant surveyed portions of West Flamborough Township during May of 1794, where he found "plains" in the first ten lots of the second concession. Along the third concession, lots 12 through 19 were described as

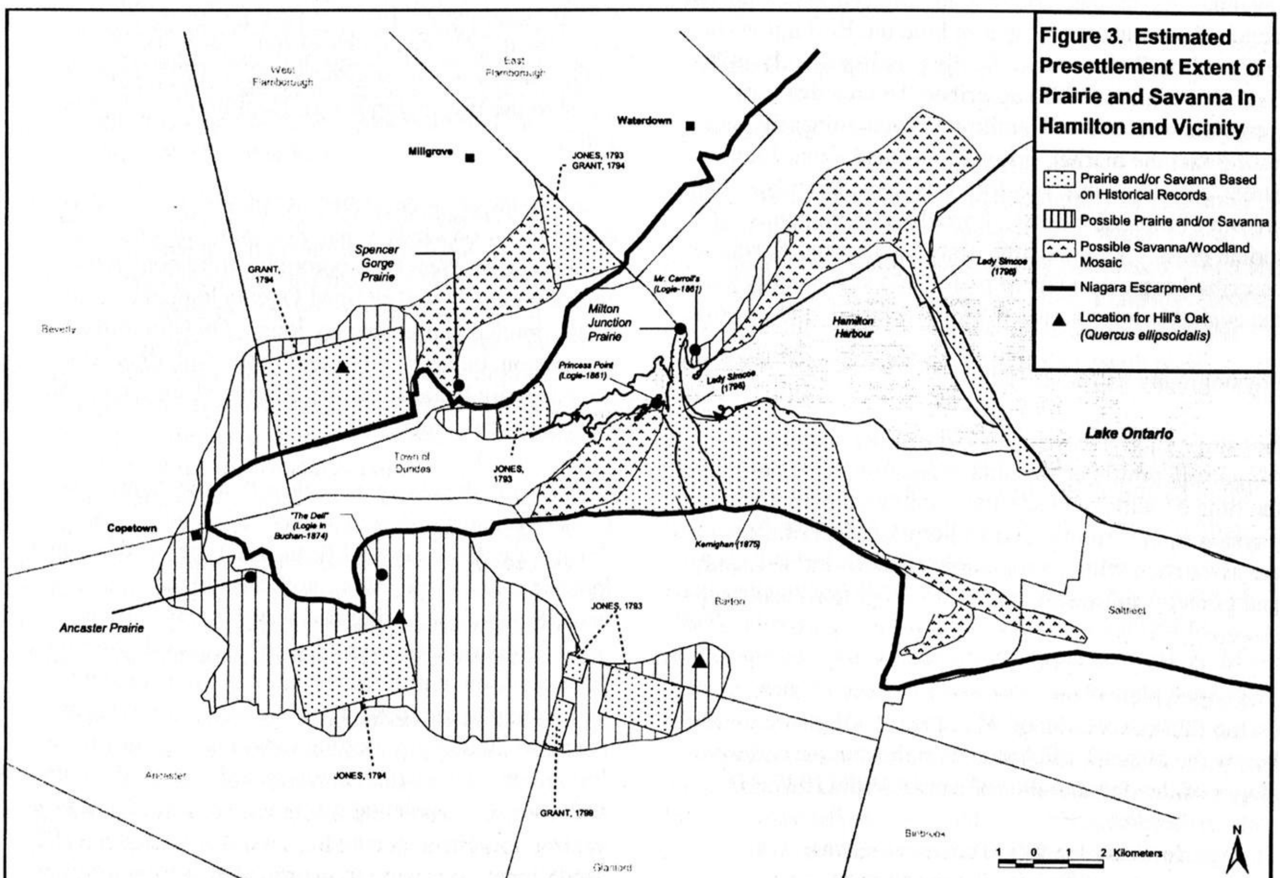

Figure 3. Estimated Presettlement Extent of Prairie and Savanna In Hamilton and Vicinity

"pine chestnut oak - open woods," lot 20 as "open woods oak chestnut" and lots 21 through 26 as "plains - wood the same."

Augustus Jones surveyed a line between concessions 2 and 3 in the Township of Ancaster in 1794. Lots 43 through 41 were described as "plains - sandy soil," lot 40 as "flat plains," lots 39 and 38 as "plains - sandy soil," lot 37 as "plains" and "a black oak tree marked," lot 36 as "a white oak tree marked," and lot 35 as "hilly" and "small timber - oak, pine."

John Stegman (1797) surveyed the upper fifth concessions of the Township of Beverly and resurveyed the boundary, describing part of the east line along the first and second concessions as "white and black oak plains."

Stegman surveyed the Township of Glanford in 1799, except for the first concession which was, as noted above, surveyed by Jones (1793). Part of Lot 1 of concession 2 was described as "oak plains."

Taken together, the areas described as "plains" in the original land surveys total some 2400 ha.

Landmarks

Sources other than the original survey records indicate that other parts of the Hamilton area were prairie and savanna. As outlined above, Lady Simcoe described and sketched savanna landscapes at both the Burlington Bay or Hamilton Beach, and at Burlington Heights (Hamilton Bar). Kernighan (1875) described the area that now forms the west end of Hamilton as predominantly prairie, noting that the market, originally located along John Street, stood on what was formerly "...a particularly dense growth of this...shrubbery..." amidst a "...monotony of Indian grass." Collectively, Lady Simcoe and Kernighan described some 1400 ha as prairie and savanna beyond the available information from the original land surveys.

Physiography and Soils

Not surprisingly, those areas highlighted above as supporting prairie or savanna vegetation, ie. "plains," at the time of settlement are associated with particular physiographic features and soil types. Most of these areas are associated with combinations of well-drained sandy and gravelly substrates, complex topography, and steep slopes.

The "open plains" on "sandy soil" in lots 16 through 19 on the first concession of West Flamborough are located below the Niagara Escarpment on the complex, steep slopes of the Dundas alluvial fan (Karrow 1987). The soils in this area are comprised of the well-drained Springvale sandy loam (Presant et al. 1965). This is where the town of Dundas is now situated.

Above the escarpment, where Grant's "plains" were situated on the rolling topography of West Flamborough's second concession, the soils also include Springvale sandy loam, along with Grimsby sandy loam and Brant silt loam (Presant et al. 1965).

In Ancaster, the "plains" along concessions 2 and 3 were located on the Summit or Copetown delta, which is a deltaic sand and gravel deposit (Heagy 1995, Karrow 1987). Again the soils are mainly Springvale sandy loam, along with Grimsby sandy loam and Brant silt loam. The "small oak and pine" described by Jones along the Beverly–Ancaster boundary were associated with Grimsby sandy loam on complex topography with fairly steep slopes (Presant et al. 1965).

The "...monotony of Indian Grass..." between "the mountain and the bay" described by Kernighan (1875), where portions of the City of Hamilton (Westdale and West Hamilton) are now situated, occurred on the silty sands of a lagoonal plain that formed behind the Hamilton Bar (Karrow 1987). To the east of the bar is the main Iroquois plain, with the substrates likewise being stratified silty sands (Karrow 1987).

The hill that Lady Simcoe described in 1796 as "...quite like a park, with large oak trees dispersed, but no underwood.." was the Hamilton Bar, also known as the Burlington Heights (Karrow 1987). The area of "...good galloping ground on fine turf by the side of the lake...[near the]...King's Head Inn..." was likely in an area of Grimsby sandy loam (Presant et al. 1965) extending out onto the Burlington Bar or Hamilton Beach (Karrow 1987).

A few of the areas described as "plains" by the surveyors do not occur on sandy soils. For example, on lots 22 through 26 on West Flamborough's third concession, the soils are mainly well-drained Oneida loam and imperfectly drained Chinguacousy loam. On Glanford's first concession, between lots 1 and 6, the well drained soils are primarily Brant silt loam, Brantford silt loam, and Grimsby sandy loam.

Considering the above, it is clear that the "plains" were primarily associated with areas dominated by the Springvale, Grimsby, and Brant soil types as described by Presant et al. (1965), along with the old and active beach bars. Soils of the Springvale series are well drained, with 30 to 90 cm of sand overlying coarse gravel. Springvale soils occur on plateau-like areas with level to gently undulating topography. The Grimsby soils occur on gently to moderately sloping topography. They have formed on well-drained medium and fine sandy loam and are prone to erosion and droughtiness. The Brant soils are usually composed alternating layers of silt loam and fine sandy loam of varying thickness. Brant soils occur on gently rolling to moderately undulating topography and are easily eroded.

The Springvale, Grimsby, and Brant soil types are concentrated in a horseshoe-shaped ring surrounding the upper Dundas Valley, extending from Spencer Gorge above the north escarpment wall of the Dundas Valley, around to Copetown in the west,and above the escarpment in Ancaster. Below the Niagara Escarpment, these soils types occur on the site of the town of Dundas, along the Burlington Heights (Hamilton Bar), and between the Aldershot Bar and the bluffs along the north shore of Burlington Bay and further east. Similar soils occurred on the south side of Burlington Bay along the Hamilton Bar, at the base of the escarpment and, to some extent, towards the bay itself. Unfortunately, no soil mapping is available for the area where Hamilton now stands (Presant et al. 1965).

Summary - presettlement extent of Hamilton's prairie and savanna

The presettlement extent of prairie and savanna, based on historical records, is shown on Figure 3. Unambiguous original land surveys, along with the accounts of Lady Simcoe (1796) and Kernighan (1875) account for some 3800 ha in Hamilton and vicinity. Since these early accounts do not provide detailed estimates of tree cover, it is often difficult to determine whether the term "plains" refers to prairie, savanna, or both in a particular instance. These areas are concentrated around Burlington Bay (ie. Burlington Heights, Hamilton Beach, Iroquois Plain), at Dundas (alluvial fan), and sandy areas above the Niagara Escarpment, forming a horseshoe shape around the western end of the Dundas Valley.

It should be recognized that a complete land survey record for the area around Hamilton does not exist. Consequently, some areas that may have supported "plains" could have existed elsewhere in the region. Figure 3 shows the possible extent of these areas, based mainly on the soils, topography, and records of prairie and savanna indicator species. An additional 5000 ha are thought to possibly have supported prairie and savanna vegetation, giving a theoretical maximum of 8800 ha. The largest area so mapped is the horseshoe-shaped band surrounding the western end of the Dundas Valley. This area was mapped on the basis of soils, ambiguous land survey records, historical records of indicator species and the presence of a prairie remnant (the Ancaster Prairie) and indicators such as *Quercus ellipsoidalis* (Hill's Oak).

Some other areas have been mapped on Figure 3 as possibly supporting a savanna-woodland mosaic. These areas were generally described as "oak-chestnut" stands in the original surveys (if available). They occur on suitable soils and have either historical or recent records of prairie and savanna indicator species.

Although no original land surveys were available for the first concession of East Flamborough along the north shore of Burlington Bay, there is some evidence to suggest that this area may have supported a mosaic of savanna, oak woodland and forest, and smaller prairie patches. Gillespie et al. (1971) mapped Springvale sandy loam along the Aldershot Bar, with fairly extensive areas of Grimsby sandy loam between the bar and Burlington Bay. Numerous historical and recent reports of prairie and savanna species are from this area (Goodban 1995, see section on "Floristic Composition" below). One plant species designated as endangered in Ontario, *Pycnanthemum incanum*, grows in open oak woodland along the Lake Ontario shoreline bluffs in this area (Crins 1986). The only Canadian stations for this species occur in this general vicinity (Crins 1986, Goodban 1995). Highway 2, which parallels the north shore of the bay, is called "Plains Road."

Although not mapped, small areas of prairie and savanna could have existed among the "oak-chestnut" forests of the Dundas Valley, on the silty and clay soils associated with dry ridges and steep, south-facing slopes. Scattered recent occurrences of prairie species are known from the Dundas Valley (Goodban 1995). Although the minimum estimated extent of prairie and savanna in Hamilton and vicinity is approximately 3800 ha, a figure of 5000 to 6000 ha may be more realistic, considering the preceding analysis.

Floristic Composition

Early botanists

The history of floristic work in the vicinity of Hamilton has been documented by Pringle (1995), which served to focus the present study onto four key references which are discussed below in chronological order. Plausible records of "prairie and savanna" plant species compiled by the early botanists are listed in Table 1 along with more recent records.

William Craigie, Sr. and William Craigie, Jr. (1854) published a list of species observed and identified in the vicinity of Hamilton, with phenological data. Whether the Craigies had a herbarium is not clear and no specimens collected by them are known to be extant (Pringle 1995). Nevertheless, their list includes a number of prairie species, many of which are quite distinctive. Most notable in the context of southern Ontario are the records for *Baptisia tinctoria*, *Euphorbia corollata*, *Liatris cylindracea*, *Lupinus perennis*, and *Gentianella quinquefolia*. Only the latter has been documented locally in recent years (Goodban 1995) and *Baptisia tinctoria* has not been recorded since the publication of the Craigies' paper.

In 1862, Judge Alexander Logie published a paper on the plants of Hamilton and vicinity in the *Annals of the Botanical Society of Canada*. His interpretation of "vicinity" was rather broad, including records from Galt (now Cambridge), Paris, and London. The records from the more distant locations were annotated as such and, consequently, they are excluded from the discussion that follows and the list presented in Table 1. Logie's list did not include some families, such as the Graminae, Cyperaceae, Juncaceae and Salicaceae. Pringle (1995) noted that the value of Logie's paper is diminished by the loss of most of the documenting specimens. Relatively few of Logie's specimens are extant in Canadian herbaria. However, Logie's list does provide plausible reports of prairie species. His list is especially valuable in that it documents the occurrence of prairie plants at particular locations. Logie collected prairie plants such as *Polygala senega, Polygala sanguinea, Helianthus divaricatus, Hypoxis hirsuta,* and *Lobelia spicata* from Prince's Island (now Princess Point) along the south shore of Cootes

Table 1. Species with prairie and savanna affinities reported from the vicinity of Hamilton, Ontario. Historical reports were by Craigie and Craigie (1854)[C], Logie (1862)[L], Buchan (1874)[B], Dickson and Alexander (1897)[D]. Many post-1950 records are known from Pringle's (1969) checklist [P], based largely on collections at HAM made in the early 1950s by Aleksander Tamsalu. Other post-1950 records by numerous botanists and naturalists are documented in Goodban (1995)[G]. Records from the Aldershot - Waterdown area on the boundary between Hamilton-Wentworth and Halton Regions are based on Axon (1989)[A] and Crins (1986)[W]. Nomenclature follows Morton and Venn (1990) except for *Panicum praecocius* A.S. Hitch. & Chase. Provincial (or subnational) ranks are given for those species considered extremely rare (S1 - usually 5 or fewer occurrences), very rare (S2 - usually 6 to 20 occurrences) or rare to uncommon (usually 21 to 100 occurrences) in Ontario (based on Oldham 1996). Provincially rare species are listed in **bold.**

P,G	*Amelanchier alnifolia*
B,D,P,G	*Andropogon gerardii*
L,B,D,P,W,G	*Anemone cylindrica*
C,G	*Artemisia ludoviciana*
C,L,B,D,P,W,G	*Asclepias tuberosa*
B,D,P,W,G	*Aster laevis*
B,D,P,G	*Aster oolentangiensis*
C (S2)	***Baptisia tinctoria***
D (S2)	***Bouteloua curtipendula***
D,P,G	*Bromus kalmii*
G (S2)	***Carex bicknellii***
C,L,B,D	*Castilleja coccinea*
C,L,D,P,G	*Ceanothus americanus*
G	*Ceanothus herbaceus*
C,D,P,G	*Cirsium discolor*
C,L,B,D,P,G	*Comandra umbellata*
C,L,B,D,P,G	*Desmodium canadense*
C,B,D,P,A (S3)	***Desmodium cuspidatum***
C,B,D,P,A	*Desmodium paniculatum*
D (S2)	***Desmodium rotundifolium***
D,P,G	*Elymus canadensis*
C	*Euphorbia corollata*
C,G (S2)	***Gentianella quinquefolia***
B,D,P	*Helianthemum canadense*
B,D,P,W,G	*Helianthus divaricatus*
C,L,B,D,P,G	*Helianthus strumosus*
B,D (S2)	***Hieracium venosum***
C,L,B,D,P (S3)	***Hypoxis hirsuta***
A	*Lechea intermedia*
B,D (SX)	***Lechea minor***
L,B,D,P,W,G	*Lespedeza capitata*
C,L,B,D,P,A,G	*Lespedeza hirta*
C,A,G	*Lespedeza intermedia*
C,D (S3)	***Liatris cylindracea***
B,D (S2)	***Linum virginianum***
B,D (S3)	***Lithospermum canescens***
D,G (S1)	***Lithospermum incisum***
C,L,D,P,G	*Lobelia spicata*
C,D (S3)	***Lupinus perennis***
C,L,B,D,G	*Lysimachia quadriflora*
D	*Minuartia michauxii*
C,L,B,D,P,W,G	*Monarda fistulosa*
L,D (S1)	***Monarda punctata***
P (S3)	***Panicum praecocius***
P,G	*Panicum virgatum*
L,B,D,P,G	*Penstemon hirsutus*
D,P,G (S1?)	***Phlox subulata***
L,B,D (S2)	***Platanthera leucophaea***
D	*Polygala polygama*
C,L,B	*Polygala sanguinea*
C,L,B,D,P,G	*Polygala senega*
B,D,P,A,G	*Polygala verticillata*
D	*Potentilla arguta*
P,G	*Pycnanthemum virginianum*
G (S3)	***Quercus ellipsoidalis***
C,B,D,P,G	*Ranunculus fascicularis*
D,A,G	*Rhus aromatica*
B,D,P,W,G	*Schizachyrium scoparium*
P,G (S2)	***Scirpus clintonii***
B,D,G	*Solidago ptarmicoides*
B,D,P,G (S3)	***Solidago rigida***
D,P,G	*Sorghastrum nutans*
P,G	*Spartina pectinata*
D (S1S2)	***Sporobolus asper***
B,D,G	*Sporobolus cryptandrus*
D,P,G	*Vaccinium pallidum*
C,B,D,P,G	*Viola sagittata*

Paradise. Logie's collections from Princess Point fit well with Kernighan's description of the area. He collected *Lysimachia quadrifolia* and *Asclepias tuberosa* at "Mr. Caroll's" which is the present day location of Woodland Cemetery near Caroll's Point on the north shore of Burlington Bay. *Ceanothus americanus* was collected "along the sides of the road to Waterdown" [Snake Road] and *Penstemon hirsutus* was collected from "Waterdown Road, near Burlington Heights." *Monarda punctata* was reported from Bellhouse Farm in East Flamborough. *Platanthera leucophaea* was noted at a "marsh near Millgrove."

John Milne Buchan collected plants in the Hamilton area in the early 1870s. In 1874 he published a list of species supposedly represented in Logie's herbarium including some added since Logie's 1862 paper, along with a shorter list presenting the results of his own botanizing. Based on Buchan's list of specimens contained in Logie's herbarium, Logie also collected *Lespedeza repens*, *Lespedeza violacea* (probably *L. intermedia*), and *Hieracium venosum* from "the Dell, Ancaster." The loss of Logie's specimens is most unfortunate in this case since *Lespedeza repens* has not been confirmed as occurring in Ontario (Morton and Venn 1990). Buchan's own "supplementary" list contains several records of interest, including *Lechea minor*, *Desmodium cuspidatum*, *Solidago ptarmicoides*, *Solidago rigida*, *Schizachyrium scoparium*, and *Sorghastrum nutans*.

The most extensive of the early plant lists, including Potamogetonaceae, Graminae, Cyperaceae, Salicaceae, etc. was compiled by John Martin Dickson and Andrew Alexander (1897). Although Alexander also collected specimens from the Georgian Bay islands where he had a summer home, most of his botanizing and all of Dickson's was done in Hamilton and vicinity (Pringle 1995). Many of their "doubtful" specimens were confirmed by John Macoun (Dickson and Alexander 1897) who was employed as Naturalist at the Museum of the Geological Survey of Canada (Pringle 1995). Macoun had already completed those portions of his catalog that dealt with vascular plants, so Dickson and Alexander's specimens were not cited therein. Dickson and Alexander included species listed by previous authors, acknowledging them in their checklist when species previously noted had not been relocated by them. Many of the prairie and savanna indicators mentioned above were relocated by Dickson and Alexander. Among the additions to the prairie and savanna flora of the area were *Bouteloua curtipendula*, *Bromus kalmii*, *Desmodium rotundifolium*, *Elymus canadensis*, *Lithospermum incisum*, *Minuartia michauxii*, *Polygala polygama*, *Potentilla arguta*, *Rhus aromatica*, *Sorghastrum nutans*, and *Sporobolus asper*. Rare species such as *Desmodium cuspidatum*, *Hieracium venosum*, *Hypoxis hirsuta*, *Lechea minor*, *Liatris cylindracea*, *Linum virginianum*, *Lupinus perennis*, *Monarda punctata*, *Platanthera leucophaea*, and *Solidago rigida* were all listed once again by Dickson and Alexander (1897).

Several interesting species listed by the early botanists of the area have been omitted from the preceding discussion and from Table 1. These exclusions, including *Aster dumosus* var. *strictior* and *Aster praealtus*, were based on the high number of apparently misidentified species of *Aster* listed by the various authors. Unlike many of the other records cited above, these species do not occur in other prairie and savanna remnants documented in south-central Ontario. In the absence of substantiating voucher specimens, these questions can likely never be resolved with any certainty.

Recent floristic work

During the 1950s, Aleksander Tamsalu undertook what is arguably the most rigorous floristic survey ever undertaken in the vicinity of Hamilton. Tamsalu delineated 270 ecological units on properties owned by the Royal Botanical Gardens, which include land around Cootes Paradise and parts of the Burlington Heights and Aldershot Bar. Some 10,000 specimens documenting 800 species were collected by Tamsalu (Pringle 1995), of whom a biography has been published by Lord (1980). Tamsalu's collections were listed along with other floristic data by Pringle (1969). The vast majority of his collections are housed at HAM. Among Tamsalu's collections were *Panicum praecocius*, *Panicum virgatum*, *Pycnanthemum virginianum*, *Scirpus clintonii*, and *Spartina pectinata*. Almost 60% of the indicator species listed in Table 1 have been reported by Pringle (1969). *Ceanothus herbaceus* and *Solidago ptarmicoides* were observed at Cootes Paradise by Steve Varga in 1994 (Riley et al. 1996, specimens at TRT). Many of these records come from dry oak woodland (canopy closure under 60%) rather than from savanna or prairie (Riley et al. 1996). It has been noted (Riley et al. 1996) that some of these drier oak forests were dependent on fire for the maintenance of their semi-open canopies and ground flora rich with savanna indicators. The suppression of fire around Cootes Paradise has resulted in the apparent decline or extirpation of a number of savanna species (Riley et al. 1996).

In the early 1980s, Don Faber-Langendoen conducted some reconnaissance-level field work on some small prairie patches perhaps covering 1 ha along railway lines at the "Milton Junction" (Faber-Langendoen, unpublished field notes and pers. comm.; see Figure 3). These small areas, although considered disturbed, were mapped by Langendoen and Maycock (1983). They were subsequently dropped from Faber-Langendoen's thesis research (Faber-Langendoen 1984). Faber-Langendoen's field notes listed a number of prairie species, with the prairie grasses *Andropogon gerardii*, *Schizachryium scoparium*, and *Sorghastrum nutans* frequently dominating patches alongside the railway lines (Goodban, pers. obs.). Other prairie species known from the Milton Junction include *Anemone cylindrica*, *Elymus canadensis*, and *Solidago rigida* (Goodban, pers. obs.). The substrates in this area are mainly cemented gravel over sands on what is the northern terminus of the Burlington Heights or Hamilton Bar (Goodban pers. obs.).

Ian Macdonald conducted a detailed floristic survey of the Spencer Gorge area in 1991. Spencer Gorge is located above the Town of Dundas, cut into the south-facing slope of the Niagara Escarpment. This area is in close proximity to the large area along West Flamborough's second concession that was described as "plains" by Grant in 1794. Although this natural area is predominantly forested, there are some fairly open, dry, valley rim woodlands and occasional small prairie patches along the valley crest (Riley et al. 1996). These areas probably cover less than 0.5 ha (Goodban pers. obs.). A number of plant species typical of prairie and savanna occur here, including *Andropogon gerardii*, *Asclepias tuberosa*, *Bromus kalmii*, *Elymus canadensis*, *Helianthus divaricatus*, *Lespedeza hirta*, *Lespedeza capitata*, *Monarda fistulosa*, *Polygala verticillata*, *Schizachryium scoparium*, *Sorghastrum nutans*, *Spartina pectinata*, and *Sporobolus cryptandrus* (Riley et al. 1996). A number of species typical of open oak woodland also occur here, including the provincially rare *Aureolaria virginica* (Riley et al. 1996).

In 1993, a 0.5-ha, high-quality prairie remnant was discovered by Jack Gartshore and briefly surveyed by Donald A. Sutherland (pers. comm.). This remnant is on a steep south-facing slope located 2.5 km SE of Copetown. The soils are Grimsby sand loam (Presant et al. 1965, Goodban pers. obs.). Much of the site is a mesic to dry-mesic, *Sorghastrum nutans*-dominated prairie with *Schizachryium scoparium* dominating the drier slope crest (Riley et al. 1996; Goodban pers. obs.). Patches of prairie grasses also extend along the nearby roadside. Most notable at this site is the discovery of the provincially rare *Carex bicknellii* by Sutherland (MICH). Other indicator species at this site include *Andropogon gerardii*, *Aster laevis*, *Aster oolentangiensis*, *Lespedeza capitata*, and *Monarda punctata* (Sutherland field notes, Goodban pers. obs., Riley et al. 1996).

During 1991, an intensive program of biological field work was undertaken as part of the Hamilton-Wentworth Natural Areas Inventory (NAI) Project (Heagy 1993, 1995). The field observations from this project formed the basis of the plant checklist for the Regional Municipality of Hamilton-Wentworth, which also incorporated post-1991 information (Goodban 1995). In addition to the species mentioned above, several others have been discovered in the region, the most notable of which is *Quercus ellipsoidalis* (Hill's Oak). This species is considered typical of oak savanna and oak barrens (Curtis 1959, White 1983). The Hamilton stations for *Q. ellipsoidalis* are among the easternmost in Ontario (P.W. Ball, pers. comm.) and these are more than 400 km from the nearest population in Michigan (Ball 1981). Using the maps of "oak plains" and related features prepared by Wood (1961) for Dumfries Township, Ball (1981) plotted records of *Q. ellipsoidalis*, noting a close correlation between the present distribution of *Q. ellipsoidalis* and the areas of vegetation suitable for it in 1816-17. The Hamilton stations for *Q. ellipsoidalis* are mapped on Figure 3, corresponding quite closely to areas described as "plains" in the original land surveys. Similar distributions patterns exist for most of the prairie and savanna species mentioned above, but these have not been plotted.

Present extent of prairie and related vegetation

It is clear that only a few hectares of prairie vegetation now remain in Hamilton and vicinity. These remnants include the Ancaster Prairie (0.5 ha), the Milton Junction site (0.5–1.0 ha approx.) and Spencer Gorge (0.3–0.5 ha approx.). Elsewhere in the region, scattered populations of prairie species persist in disturbed sites such as pipeline and hydro corridors, but these have not formed patches of prairie vegetation (Goodban 1995, Goodban pers. obs.). Considering that several of the known remnants have only been documented in recent years, eg. the Ancaster Prairie, it is certainly conceivable that other remnants await discovery in this area. No examples of oak savanna have been documented recently from the area. Open oak woodlands (closure 40–60%) occur on dry ridges in the Dundas Valley, along the escarpment rim at Spencer Gorge and elsewhere, and at Cootes Paradise (Riley et al. 1996). The extent and floristic composition of these oak woodlands are the subject of further research by the authors.

If a generous estimate of 3.0 ha of remnant prairie is considered, then less than 0.08% of the original 3800 ha (minimum) of prairie and savanna remains in the vicinity of Hamilton.

Juxtaposition

The "plains" around Hamilton and vicinity are located approximately 18 km southeast of the Branchton prairie remnants (Gore and Storrie Limited 1993) and approximately 16 km east of the plains mapped by Wood (1961) near the town of St. George in Brant County (Figure 1). The Hamilton "plains" are located approximately 19 km northeast of the Brantford prairie remnants.

To the east of Hamilton, along the north shore of Lake Ontario, prairie remnants occur at Bronte Creek (House and Carleton 1988), Lorne Park (Gore and Storrie 1993), and Lambton Park (Gore and Storrie 1993). The High

Park Oak Woodlands contains areas of *Quercus velutina* savanna and a rich flora containing many prairie and savanna indicators (Varga 1989). Lambton Park and High Park are both considered to be remnants of the "Humber Plains" which extended from the Humber River east to High Park and northward to Scarlett Road, comprised of *Quercus-Pinus* woodland that frequently burned (Gore and Storrie 1993).

Considering the extent of the prairie and savanna vegetation in the vicinity of Hamilton, it is not difficult to conceive of a somewhat discontinuous band of such vegetation stretching from the Brantford area, up towards Galt and across that lobe of the Norfolk sand plain that extends towards Hamilton. This vegetation likely occurred discontinuously along the Iroquois Plain on the north shore of Lake Ontario, eastward to the Trent River.

Origin and maintenance of prairie and savanna

A number of hypotheses have been developed to explain the occurrence of prairie and savanna vegetation, including anthropogenic (Day 1953, Curtis 1959, Dorney and Dorney 1989), climatic (Deevey and Flint 1957, Szeicz and MacDonald 1991) and edaphic factors. It has been suggested by a number of researchers that all three are closely related and likely responsible for the origin and continued persistence of this vegetation in Ontario (Rogers 1966, Reznicek 1983, Reznicek and Maycock 1983, Faber-Langendoen 1984, Bakowsky 1988, Catling et al. 1992, Gore and Storrie Limited 1993).

Native peoples

There is a long history of occupation by native peoples in the vicinity of Hamilton. An archaeological site assigned to the Broad Point Late Archaic was found at the Hamilton Golf Club (Howey 1977, Kenyon 1980 cited in Ellis et al. 1990). This period is generally dated at between 4000 and 3000 B.P. Broad Point sites in southwestern Ontario were often located within easy access to sand plains which supported oak-hickory forests (Kenyon and Payne 1981 cited in Ellis et al. 1990). Ellis et al. (1990) suggest that Broad Point sites represent a culture centred on terrestrial resources and in particular, mast forests that would have been rich in game animals.

A site at Princess Point in Cootes Paradise was assigned to the Middle to Late Woodland transition (Fox 1990). The Princess Point Complex is named after this site in Cootes Paradise. The date and duration of the complex is the subject of some debate, with an initial date of 1300 to 1250 B.P. being suggested by Fox (1990). Faunal remains at the site included a typical array of subsistence and furbearer animals, supporting the notion that the people of the Princess Point Complex were primarily hunter-gatherers. Corn horticulture has been attributed to the Princess Point site, but since this site is multi-component it may be from the Late Woodland. Tobacco may also have been grown by the Princess Point peoples (Fox 1990).

Williamson (1990) mapped a concentration of Early Iroquoian sites (900 to 1300 A.D.) from the vicinity of Hamilton. The Early Iroquoians seemed to have preferred sandy soils to locate their base settlements around which corn was likely grown (Williamson 1990). Similarily, Dodd et al. (1990) mapped concentrations of Middle Ontario Iroquoian (1300 to 1400 A.D.) sites from the Hamilton area. During this period, a greater reliance on corn cultivation has been suggested. The preference for sandy soils and the prominence of white-tailed deer as a dietary supplement (Dodd et al. 1990) is of interest. Lennox and Fitzgerald (1990) noted that historic (the period after European contact) Neutral Iroquois sites occurred in clusters around the western end of Lake Ontario and across the Niagara Peninsula. The neutral period extended from 1400 to 1650 A.D.
Again, the sites tend to occur in areas of sandy soils (Lennox and Fitzgerald 1990). In 1796, Lady Simcoe made several references to meeting "Indians" near the King's Head Inn in her diary.

Day (1953) and Curtis (1959) provide evidence that native peoples used fire to maintain open areas, citing references that this was done to enhance visibility for hunting and to encourage the growth of grass for deer and elk. Gourlay (1822) defined the word "plain" as "...a tract...where the timber is thin or free of under-brush, generally kept in this state by successive burnings." To the east of Hamilton, just south of Rice Lake, Traill (1836) wrote of the Rice Lake plains:

> these...were formerly famous hunting-grounds of the Indians, who, to prevent the growth of timbers, burned them year after year...Sufficient only was left to form coverts; for the deer resort hither in great herds for the sake of a peculiar tall sort of grass with which these plains abound, called deer-grass, on which they become exceedingly fat at certain times of the year.

Evidence of fire in the Hamilton area was recorded in 1794, when Augustus Jones described lot 8 of Glanford's first concession as "pine, some oak, the greatest part has been killed by the fire, underbrush thick."

Catling et al. (1992) noted that for fires set by native peoples to have had a significant effect on the vegetation of a region, there would need to be a long history of occupation. As outlined in the preceding paragraphs, there is a long history of occupation by native peoples in the vicinity of Hamilton. Catling et al. (1992) noted that the Rice Lake area has a long history of occupation, and cited references that Rice Lake was part of a major Indian trade route linking Georgian Bay with Lake Ontario. Reznicek (1983) noted the association of prairie remnants with the trading routes of native peoples, suggesting that burning or other activities to keep these routes open allowed a relict prairie flora to persist. Hamilton was the eastern terminus of a portage and land route between the Grand River at Brantford and the head of Lake Ontario (Lady Simcoe 1792-96). Considering the long history of occupation and Hamilton's important geographical location on a portage and land route, it is conceivable that native peoples did repeatedly burn or otherwise clear areas of land to improve their hunting grounds or to maintain agricultural land, settlement clearings, and trails.

Climatic change

Karrow and Warner (1990), considering the sequence of vegetation change in southern Ontario on the basis of palynological evidence, suggested that the climate following deglaciation was initially colder and drier than at present. Atmospheric moisture levels probably increased rapidly, followed by a more gradual increase to the present. The inferred winter temperatures probably increased gradually to the present. However, the inferred mean July temperature gradually increased until approximately 10,000 B.P., at which point it increased more rapidly until 9000 B.P., and has since steadily decreased from this maximum period (Karrow and Warner 1990).

These gradual changes in the climate of southern Ontario differ substantially from more dramatic changes experienced elsewhere in the prairie biome, where it is documented that, during the "Hypsithermal" or "Xerothermic" period, estimated at 4000 to 8000 B.P. for the American Midwest, the Prairie Peninsula expanded its range eastward (Deevey and Flint 1957). McAndrews (1966) provided some of the first conclusive evidence that this extension took place in Minnesota. Although McAndrews (1981) originally failed to find any evidence that a Hypsithermal warming occurred in southern Ontario, more recent studies suggest that this warming did occur (McAndrews 1994, Yu and McAndrews 1994). Yu and McAndrews (1994) reported low lake levels in Rice Lake between 6000 and 4000-3000 B.P., resulting from a dry/warm climate.

Szeicz and MacDonald (1990) reported evidence that a Hypsithermal warming did take place in southern Ontario between 8000 and 6000 B.P. Based on palynological evidence from a lake near Paris, some 25 km west of Hamilton in an area that formerly supported oak savanna, it was concluded that savanna developed in the area between 6000 and 4000 years B.P., and occurred there continuously until European settlement.

Edaphic factors

On some of the complexes of dry, droughty soils and steep, south-facing slopes in the area, fire would not necessarily have been vital to maintaining prairie and savanna vegetation. Dry ridges and escarpment rims around Cootes Paradise, the Dundas Valley and Spencer Gorge all support fairly open oak woodland to the present day (Heagy 1993, Riley et al. 1996) and these have not been burned for some time.

Summary

Considering the long history of occupation, the supposed Hyspithermal warming and the soils and physiography of the Hamilton area, it is not unreasonable to suggest that these factors together contributed to the presettlement development and maintenance of fairly extensive areas of prairie and savanna vegetation. It is quite likely that, as in neighbouring Paris (Szeicz and MacDonald 1990), there was a shift to oak savanna in the sandy areas around Hamilton due to a warming trend between 6000 and 4000 B.P. The development of a native culture, focused on oak woodland as suggested by Ellis et al. (1990), may have occurred in association with these vegetational changes. The use of fire by native peoples may have continued since that time in a more or less uninterrupted fashion until the time of settlement. It should also be acknowledged that some areas may have been maintained in a fairly open state due to edaphic factors and periodic fires caused by lightening strikes. Some of the prairie species occurring in the area may also be relicts of shoreline communities that occurred along post-glacial Lake Iroquois and modern Lake Ontario (Crins 1986), and along the shores of periglacial Lakes Whittlesley and Warren which briefly existed above the Escarpment to the west of Hamilton (Karrow 1987).

CONCLUSIONS

At least 3800 ha (38 $km^{2)}$ of prairie and savanna occurred in Hamilton and vicinity at the time of settlement. A more realistic estimate of the extent of this vegetation is between 5000 and 6000 ha (50 to 60 km^2). These areas were dominated by prairie grasses and oaks and included many other species with prairie and open ground affinities. There is a close spatial correlation between the physiographic features and soil types that support this vegetation, the presettlement accounts, and the locations of modern remnants and populations of indicator species. There is at least some evidence that these communities became widespread between 6000 to 4000 B.P. This vegetation was likely maintained by edaphic factors and fires (natural and caused by native peoples). The prairie and savanna vegetation in Hamilton and vicinity was likely part of a much larger, discontinuous band of such vegetation extending from the Brantford and Branchton areas in the west and south to along the north shore of Lake Ontario along the Iroquois Plain and the Iroquois shoreline.

Considering that far less than 1% of the presettlement prairie and savanna remains, the remnants represent the rarest and most threatened community type in the Regional Muncipality of Hamilton-Wentworth. The development of an integrated, multi-partner strategy is urgently needed to ensure the protection and management of these significant natural communities.

Additional research is planned by the authors to further document the extent and composition of remnant prairie, savanna, and oak woodland in Hamilton and vicinity. A further examination of the correlation with archaeological sites in the area is also planned.

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ARE BUGS ENDANGERED?

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ABSTRACT: True bugs (Hemiptera and Homoptera) are seldom listed as endangered by human activities although many have been rarely encountered in the last 50 years. In leafhoppers (Cicadellidae) alone, over 500 Canadian and American species have been recorded from 5 or fewer sites each. The species that occur in California, Arizona, New Mexico and the subtropical tips of Texas and Florida cannot be assessed due to inadequate collecting in adjacent countries. In the rest of the continent there are 190 localized species rare enough to be considered as possibly endangered. It is estimated that 4 of these are restricted to the margins of the Great Lakes, 6 to bogs, swamps and coastal marshes, 15 on mountaintops, 30 on forbs in arid and semiarid areas, and 82 on native grasses, primarily on prairie and intermontane grasslands. Identification of their host plants should be followed by intensive surveys throughout areas where their hosts grow. This is necessary to establish whether populations are decreasing, or are restricted to habitats in danger of destruction. Sensitive habitats may be identified by their suites of rare or highly localized insect species. These leafhoppers are most likely to attain endangered status where their ecosystems are highly fragmented (e.g. coastal old-growth forest) or of very limited area (e.g. alkaline fen). Species are especially vulnerable on land adjacent to farms or settlements, or where species are flightless and migrate very slowly. Examples of potentially endangered species were found in tallgrass prairies, valleys of the Pacific Northwest, and lakeside areas in Manitoba and Ontario.

Key words: bogs, Cicadellidae, grasslands, Homoptera, leafhoppers, localized, mountains, prairies, rare, swamps

INTRODUCTION

Ecosystem management practices should attempt to maintain an environment in as natural a state as possible. This involves preventing the extirpation of endangered species. Increasingly, endangered status (Endangered status is a political, not a scientific concept. It is based on potential land use as well as on current status of the organism under consideration.) is being considered for insect species in prairie preserves. Large, showy species like butterflies are readily assessed as endangered. Other, smaller insects are very difficult to observe and count with any accuracy. As a result, we know far less about them than we need to know for purposes of assessing their abundance and distribution.

Small insects are not only difficult to observe in the field, but are also excessively diverse. This requires focusing studies on groups of insects that are potentially endangered. For prairie environments, the most readily studied are phytophagous insects. Among phytophagous true bugs (Hemiptera and Homoptera), the most potentially endangered species are found in leafhoppers, the family Cicadellidae. This family has over 200 prairie endemic species (Hamilton and Whitcomb 1993). Many have been collected rarely during intensive sampling over the last 50 years, yet these rare insects, and other bugs, are seldom considered as endangered by human activities.

Information on the distribution of leafhoppers is scattered through the literature. This is a first attempt to survey the records to sift out rare and localized species. Much additional work is needed to determine whether any of these species are, in fact, endangered.

METHODS

This study surveys the current literature on rare North American leafhoppers. Rare species may be artifacts of inadequate taxonomic information. Accordingly, the literature is supplemented by information from the following collections:

* Canadian National Collection of Insects, which includes Agriculture Canada s northern insect survey (1947–1961), samples by H.H. Ross in prairie areas (1950–1972), and my own collections (1963–) in southern Canada and the northern USA;

* Oregon State University collection, which includes leafhoppers mostly from surveys by P.W. Oman in the Pacific Northwest (1970–1985);

* R.F. Whitcomb's private collection from southwestern and central USA grasslands (1977–);

* R. Panzer Whitcomb's private collection from the vicinity of Chicago, Illinois (1982–).

Wind-dispersed leafhoppers are seldom found in lengthy series, and their rarity is hard to determine. Fortunately, few leafhoppers (except microleafhoppers, subfamily Typhlocybinae) are wind-dispersed. Typhlocybinae often are both poorly collected and wind-dispersed, and are not analysed here.

Rare leafhoppers have two kinds of distribution patterns: 1) the few remaining populations represent peripheral stands of a once extensive range or 2) the species is naturally localized, restricted to a very small geographical range.

The first such situation is seen in a relative of leafhoppers, a spittlebug (Cercopidae: *Philaronia canadensis* (Walley), which was once widespread in southern Ontario and Michigan, but is now known only from two peripheral populations (Figure 1). In the numerous species of leafhoppers it is difficult to survey such decreasing ranges over the whole of North America. Data is available only for southern Canada and the northern U.S. where populations have been monitored for 40 years since the publication of a faunal synopsis (Beirne 1956).

There is a much larger body of information covering the second situation: leafhoppers with apparently naturally restricted ranges. I have prepared a summary using the most recent catalog (Metcalf and Wade 1962–68). All records (except for the poorly studied subfamily Typhlocybinae) were checked in the original publications for species limited to four or fewer states or provinces of North America. Species were listed if they were found to have five or fewer known sites (and hence are possible contenders for endangered status). Species found in non-contiguous states (all species occurring in three to four states fell into this category) were deleted from the list; such a distribution pattern suggests lack of collecting in intervening areas. Subsequently, targeted species were checked for recent records in the Canadian National Collection of Insects, Ottawa, which includes much material collected by H.H. Ross and some samples from R.F. Whitcomb. Important information from the P.W. Oman collection is available from recent publications (Oman 1972, 1985, 1987; Oman and Musgrave 1975).

This study presumes that no leafhopper species is truly rare in the sense of lacking any locally large populations. Leafhoppers communicate by vibrations of the substrate, and hence cannot aggregate over large distances, as do cicadas (by sound) or silk moths (by scent). Hence, species known from only five or fewer individual specimens probably represent lack of collecting.

Over the last 23 years, I have searched for many such species in the northern U.S. and Canada. Usually this involves collecting at the site where each species has been found previously, searching for biological clues such as host associations. Knowing the host of a particular species is the most efficient aid to discovery of additional populations (if they exist). Based on the success rate of these searches, one can extrapolate for a predicted number of highly localized species; these may encompass potentially endangered species.

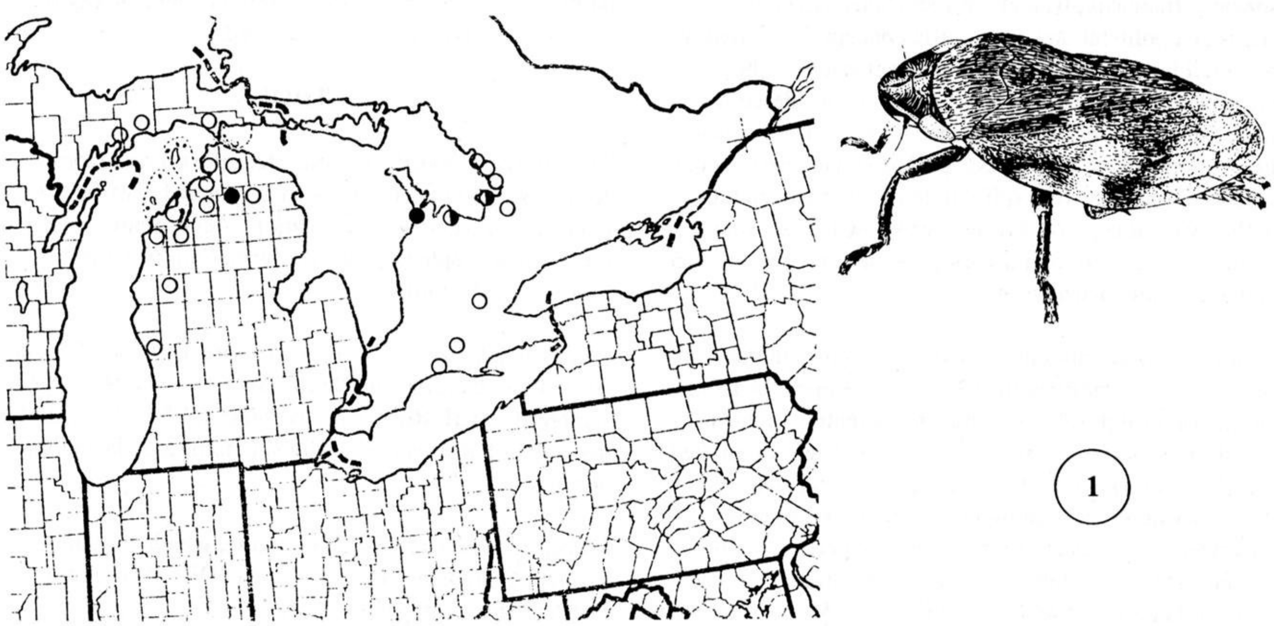

Figure 1. Distribution of the spittlebug *Philaronia canadensis* (Walley) in Ontario and Michigan. Open circle, range prior to 1950; split circle, collections taken in 1960; dot, present known range.

RESULTS

Peripheral Stands

No case of a leafhopper species becoming rare and localized in historical times has been demonstrated yet. Whenever populations are very widely scattered, numbers of leafhopper specimens are always few. This probably reflects a lack of appropriate collecting techniques rather than the endangered status of the leafhopper. Such situations are fairly numerous and are not itemized here.

In one case a leafhopper has apparently become much less common than formerly. *Aflexia rubranura* (DeLong) is now known from 28 tallgrass prairie sites, being highly abundant and prolific in some sites while very scarce in others (Figure 2). Most of the sites with large populations are at the periphery of its range. At one time it was probably a major faunal component where prairie dropseed (*Sporobolus heterolepis*) was subdominant, but it is now adversely affected by fire management regimens (Hamilton 1995) except in Illinois where it has two generations a year.

Localized Species

Over 500 species of nontyphlocybine leafhoppers are considered to be rare in Canada and the U.S. Each has been recorded from fewer than six sites in fewer than three adjacent political areas in the last 145 years. Many such species occur in California (> 150 species), Arizona (> 130), New Mexico (39), and the subtropical tips of Texas (13) and Florida (10), but how localized these species are cannot be assessed properly due to inadequate collecting in adjacent countries. Still, there are over 260 species in the rest of the continent that are sufficiently localized to be considered for endangered status. Only 61 of these occur in 2 adjacent political areas, mostly in the southwestern U.S. (Table 1). Others, confined to a single state, province, or territory, are most abundant in prairie and intermontane areas (Table 2). They include most political areas which have prairies or intermontane grasslands: Texas north of Hidalgo Co. (26 species); British Columbia, Colorado, and Oregon (17); Idaho (16); Nevada (15); Ontario; Washington state and Wyoming (9); Illinois and Utah (8); Kansas, Manitoba, Montana, and Saskatchewan (5); Alberta, Michigan, and Wisconsin (3); South Dakota (2); plus Iowa and Nebraska (1). Florida north of Palm Beach Co. (12 species) and North Carolina (8) are the two nonprairie areas with the largest such faunas. Five or fewer such species are known from 21 other political units.

These species may be grouped by ecological associations. Six species appear to be restricted to the margins of the Great Lakes; 6 to bogs, swamps, and coastal marshes; 18

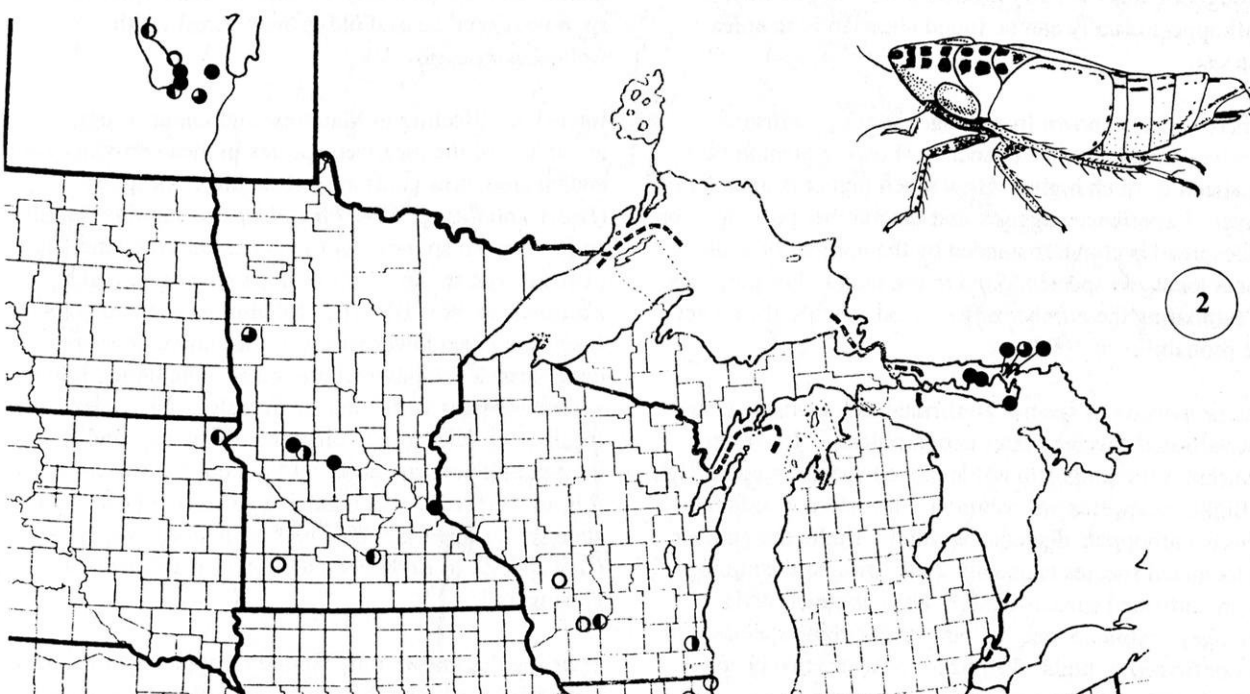

Figure 2. Abundance of the red-tailed leafhopper *Aflexia rubranura* (DeLong) at its 27 known sites. Dot, 20 or more individuals collected at a time; split circle, 4–15 individuals collected; open circle, only 1–2 individuals collected.

on mountaintops; 38 on forbs in arid and semiarid areas; 100 on native grasses (primarily on prairie and intermontane grasslands); and 93 in other habitats (Table 3).

Experience shows that searching for rare species will usually yield numerous other samples, particularly when the host is known. However, the number of rare leafhopper species is not decreasing rapidly despite intensive collecting. Such sampling turns up other rare or localized species. This is particularly true in western grasslands and deserts, where flightless females make species fairly numerous and locally restricted. For example, Oman (1987) collected numerous specimens of fivr highly localized species of *Errhomus*, all of which have flightless females. When these species were sought by R.S. Zack of Washington State University over a subsequent seven-year period, no additional populations were found, but many specimens of an additional five highly localized species were discovered (Hamilton and Zack in press).

CONCLUSIONS

Localized Species

Leafhoppers are seldom truly rare; species represented by few specimens in collections are listed here as unconfirmed records. Identification of the host plants for such leafhoppers should be followed by intensive surveys throughout areas where the hosts grow. In this way, leafhoppers usually can be found abundantly in at least one site.

Where species known from longer series (confirmed species) are sought, the chance of showing them to be localized is much higher. How much higher is uncertain as yet. Experience suggests that the number proving to be widespread is counterbalanced by the number of additional localized species found in the search. For purposes of estimating the number of localized species, then, I set the probability at 100%.

The proportion of species confirmed as localized versus unconfirmed species varies geographically. In western grasslands the proportion of localized species may be high if flightless species are common. In eastern woodlands where leafhoppers disperse readily by flight, the number of localized species is usually quite low and the number of unconfirmed species is high. On a continentwide average, I estimate that one nontyphlocybine species will be confirmed as highly localized for every two unconfirmed leafhopper species sought.

Combining 100% of the number of species confirmed as localized with 50% of the unconfirmed species yields a predicted leafhopper fauna of 190 localized species north and east of New Mixico (Table 2): 22 in Texas; 14 each in British Columbia and Oregon; 13 in Idaho; 12 in Colorado and Nevada; 10 in Florida; 8 in Washington state; 7 each in Ontario and Wyoming; 6 each in Illinois, North Carolina, and Utah; 5 each in Kansas and Montana; 4 in Manitoba; and the balance in other political areas. By far the highest number of localized species in an area without prairies or intermontane grasslands is temperate-zone Florida, with ten such species.

Endangered Species

It is not enough to know that a species is highly localized for it to be considered endangered. It is also necessary to establish whether populations are decreasing or are restricted to habitats in danger of destruction.

No studies have been conducted on any localized species to determine whether its populations are decreasing. Only one such case is known for certain: one of the two known sites for *Errhomus paradoxus* Oman was wiped out by herbicide usage (Oman 1987). Likewise, recent searches for two populations of *Errhomus reflexus* Oman have been unsuccessful, suggesting that this species is also on the wane.

Land use patterns help to determine probabilities of such local extirpations. Sites in major agricultural areas (such as tallgrass prairie) are under most intense pressure. Other highly localized and potentially endangered sites include rare habitats such as alkaline fen (with *Flexamia* sp. nov. A) and coastal old-growth forest (with *Colladonus* sp. nov. C).

Intensive collecting in Manitoba and Ontario suggest that about half of the localized species in these provinces are endangered, now confined to beachfront property (*Laevicephalus* sp. nov., *Paraphlepsius lupalus* Hamilton, and *Prairiana* sp. nov.) or to very small grassland sites (*Attenuipyga* sp. nov., *Chlorotettix* sp. nov. C and *Flexamia* sp. nov. B). The probability of endangered species is much lower westward, as native grasslands are under less developmental pressures. The larger number of western species with wingless females make some localized species more vulnerable there, especially when their populations are adjacent to major highways. Hence it is not surprising that intensive collecting in Washington state shows that more than half of the localized species (five species of *Errhomus*) there might also be considered endangered.

Four species known only from their type localities have not been found. Two have been sought unsuccessfully and are feared to have been extirpated: *Flexamia beameri* Whitcomb and Hicks and *Flexamia texana* Young and Beirne (Whitcomb and Hicks 1988). The status of one other, *Gyponana flavilineata* (Fitch), is uncertain as its type locality is unknown.

Endangered Ecosystems

Regional clumping of localized leafhopper species can highlight parts of the country where ecosystems are in jeopardy. In southern Canada and northern U.S. there are three small areas of special concern.

Between Lake Wenatchee State Park, Washington, and The Dalles, Oregon, (Figure 3, stars) are the only known sites for seven species of *Errhomus*. Five of them are rare species in Washington (Table 2) and the others are the locally abundant *E. winquatt* Oman and *E. wolfei* Oman.

All the known sites for three of the five rare leafhopper species of Manitoba lie in the lowlands around Lake Manitoba and the southwestern half of Lake Winnipegosis (Figure 4). In addition, these lands also enclose three of the five known sites for *Bruchomorpha keidensia* Doering, one of the few rare caliscelid planthoppers or piglet bugs (Fulgoroidea). These insects come from prairie sites which have the largest number of endemic leafhoppers and piglet bugs of any northeastern tallgrass prairie (Hamilton 1995). Part of the area is a wildlife sanctuary but none of it is specifically a prairie preserve.

Four of the six rare leafhoppers of Montana (Figure 5) occupy the valleys of the Blackfoot and Bitterroot rivers and the adjoining part of the Clark Fork River valley around Missoula (Figure 6, box). A fifth species, *Errhomus solus* Oman, is locally common but also restricted to the same valley system (Figure 6, crosses). Furthermore, another species is known only from the mountain range immediately to the east of the Bitterroot River (Figure 6, square). The Blackfoot River Conservation Easement is the only nature preserve in this area. No other valley system in western Montana is known to have endemic leafhoppers.

Leafhoppers have an estimated 190 localized species north and east of New Mexico, primarily in deserts, prairies, and intermontane grasslands, with smaller numbers in temperate-zone Florida and scattered sites throughout the rest of the continent. These leafhoppers are most likely to attain endangered status where their ecosystems are highly fragmented (e.g. coastal old-growth forest) or of very limited area (e.g. alkaline fen). Species are especially vulnerable on land adjacent to farms or settlements, or where species are flightless and migrate very slowly. Examples of potentially endangered species were found in tallgrass prairies, valleys of the Pacific Northwest, and lakeside areas in Manitoba and Ontario.

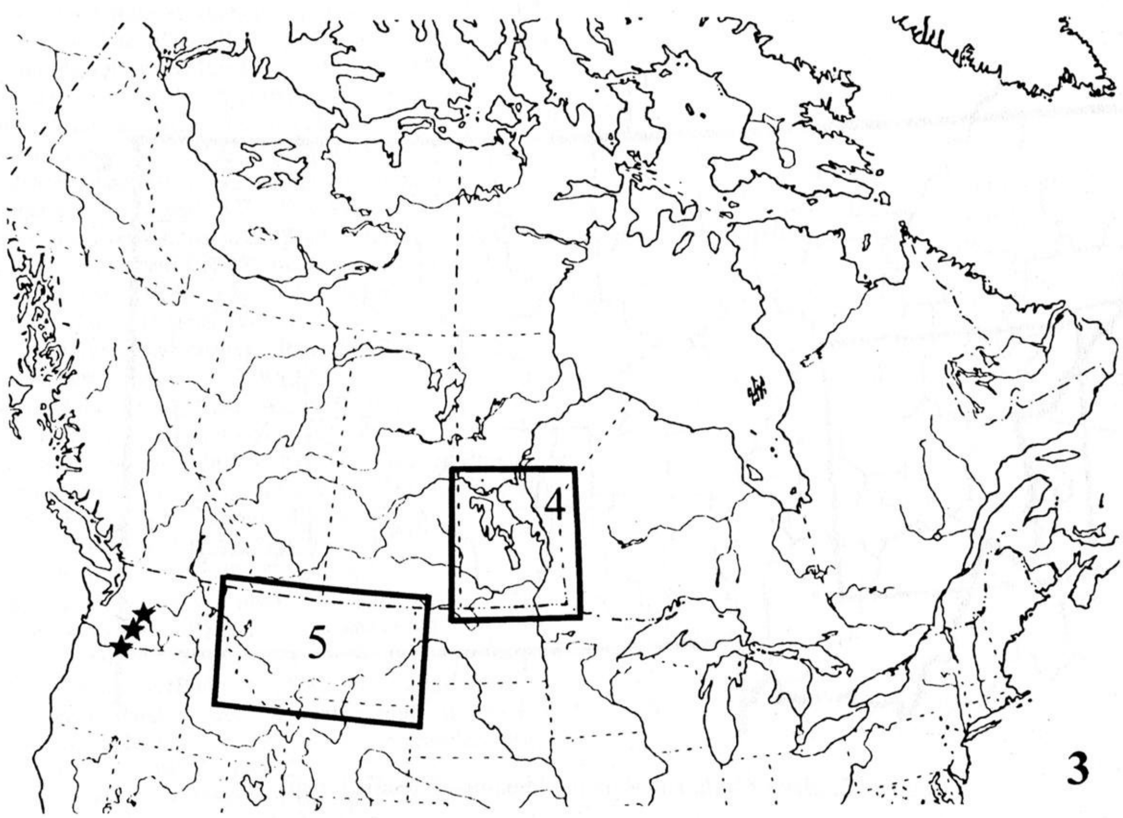

Figure 3. Canada and northern U.S. with endemism in Washington and Oregon (stars) and location of detailed maps.

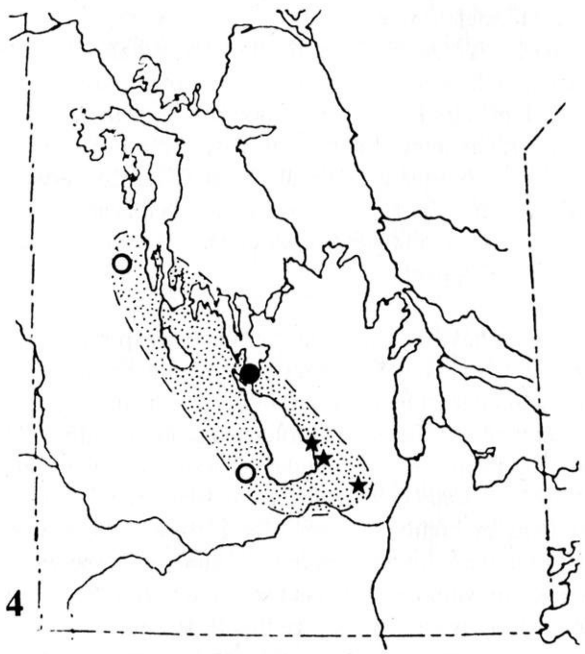

Figure 4. Endemism around Lake Winnipeg and Lake Winnipegosis, Manitoba (star, *Attenuipyga* sp. nov.; circle, *Flexamia* sp. nov. B; dot, *Macrosteles* sp. nov. D.).

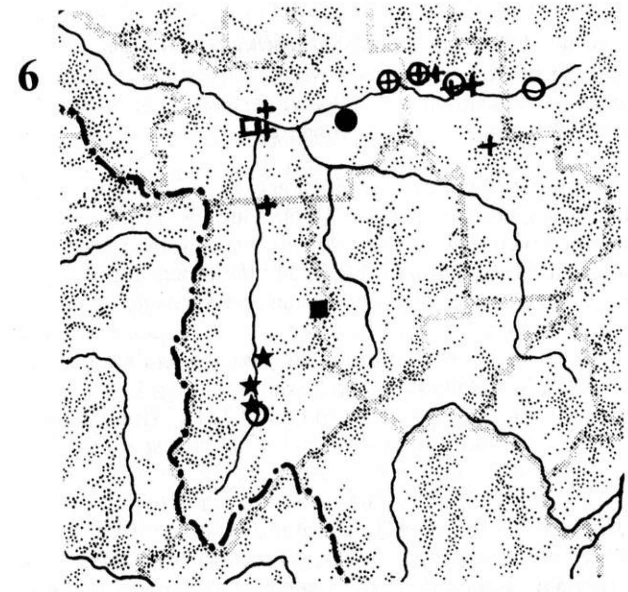

Figure 6. Endemism around Missoula, Montana (circle, *Auridius cosmeticus* Hamilton; cross, *Errhomus solus* Oman; star, *Errhomus bracatus* Hamilton and Zack; dot, *E. camensis* Hamilton and Zack; box, *E. rivalis* Hamilton and Zack; square, *Macrosteles skalkahiensis* Beirne).

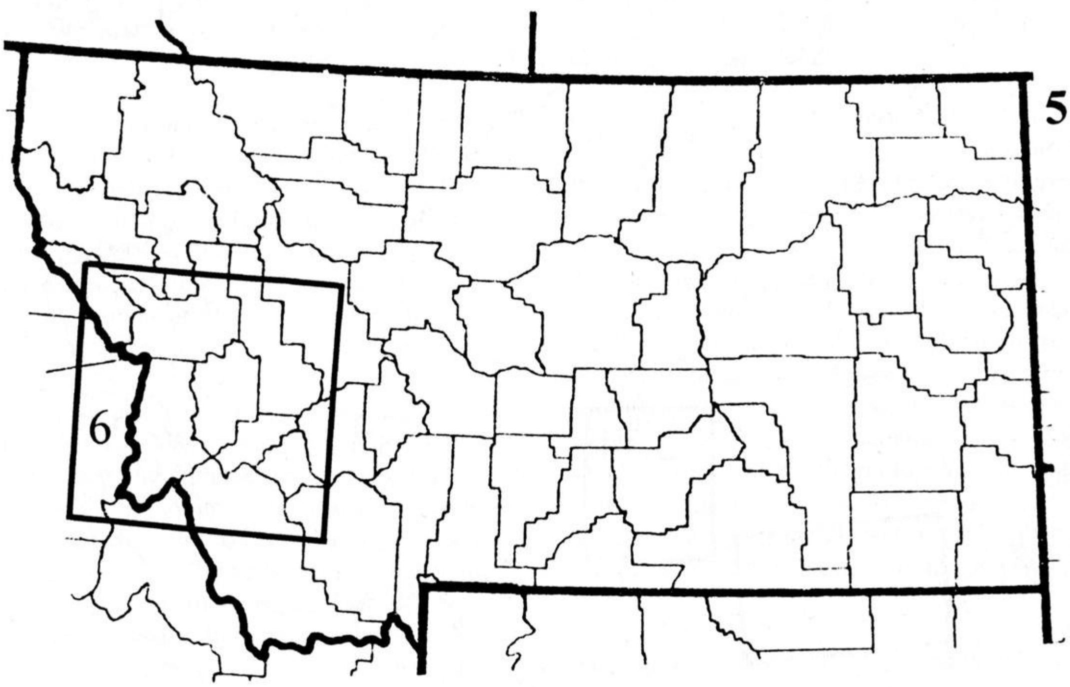

Figure 5. Map of Montana showing location of detailed map.

Table 1. Leafhopper species found in five or fewer sites in two states, provinces, or territories of North America. Date in brackets: latest record.

Aligia obesa Hepner - TX, NM (1942)
Ankosus filamentus Oman - CA, OR (1975)
Aplanus pauperculus (Ball) - CO, UT (1952)
Arundanus carolinus DeLong - NC, SC (1941)
    latidens DeLong - NC, SC (1941)
    parvulus DeLong - NC, SC (1941)
Athysanella alsa Ball and Beamer - CO, NM (1990)
    concava Ball and Beamer - NM, OK (1990)
    excavata Osborn - NE Mex., TX (1990) on *Sporobolus pyramidatus*
    mansa Johnson - NM, OK (1990) on *Sporobolus flexuosus*
    obscura Johnson - UT, WY (1990) on *Distichlis stricta*
    omani Blocker - CA, NV (1990)
    resusca Blocker and Wesley - NWT, YT (1990)
    truncata Ball and Beamer - NM, TX (1990)
    sp.nov. A - ID, MT (1992)
Ballana arma DeLong - AZ, CA (1964)
    atela DeLong - CA, OR (1964)
    delta DeLong - AZ, NM (1967)
    elexa DeLong - AZ, CA (1964)
    tiaja DeLong - AZ, Baja Calif. (1964)
    youngi DeLong - WA, OR (1985)
Bonneyana osborni (Ball) - CO, NE (1900)
Ceratagallia abrupta Oman - AZ, CA (1995)
    C. califa Oman - CA, ALTA (1996)
    C. gallus Hamilton - ID, UT (1995)
    C. modesta Hamilton - CA, OR (1995)
Chlorotettix latus Brown - FL, GA (1933)
    maculosus Brown - AR, LA (1933)
Colladonus citrinifrons (Gillette and Baker) - CO, UT (1957)
    Cribrus plagus (Ball and DeLong) - WI, IL (1980)
Cuerna alta Oman and Beamer - NM, TX (1965)
Destria sp. nov. A - NB, PEI (1983) on *Spartina pectinata*
Diplocolenus aquilonius Ross and Hamilton - AK, YT (1984)
Empoasca sp. nov. - ALTA, SASK (1996)
Eusama amanda (Ball) - AZ, NM (1948) on juniper
Eutettix minutus Hepner - OK, TX (1942)
Flexamia youngi Whitcomb and Hicks - UT, NV (1988) on *Muhlenbergia richardsonis*
Graminella floridana DeLong and Mohr - FL, GA (1967)
Gyponana fimbriata DeLong - AZ, CA (1968)
    librata DeLong - OK, TX (1964)
Hebecephalus hilaris Beamer - ID, WY (1936)
Hecalus curtus (Shaw) - CO, KS (1961)
Laevicephalus paulus Knull - AZ, NM (1972)
Lycioides mohavensis Ball - AZ, CA (1946)
Macropsis dixiensis Hamilton - NC, TN (1983) on *Prunus* spp.
Macrosteles sp. nov. A [informis Kwon] - NFLD, NS (1988)
Memnonia elongata (DeLong) - SD, IA (1995)
    spadix (Ball) - AZ, NM (1995)
Menosoma stonei (Ball) - FL, GA (1955)
Paraphlepsius spinosus Crowder - FL, GA (1975)
Platymetopius acutus (Beamer) - AZ, NM (1942)
    malvastra (Ball) - AZ, NM (1942)
    solitarius (Ball) - AZ, CA (1942) on Joshua trees
Psammotettix shoshone DeLong and Davidson - ID, NV (1971)
Spathanus aureus Knull - AZ, CA (1949) on creosote bush
Stragania hualpaiana Knull - AZ, CA (1970)
    oregonensis Beamer & Lawson - CA, OR (1970)
Telusus merus (Beamer) - AZ, NM (1937)
    sp. nov. A - ALTA, SASK (1994)
Texananus bullatus DeLong - AZ, NM (1952)
Xyphon gillettei (Ball) - AZ, CO (1936)

Table 2. Leafhopper species found in five or fewer sites in one state, territory, or province of North America, with estimated unique fauna. Asterisk (*) denotes unconfirmed species (known from five or fewer specimens).

1 LOCALIZED SPECIES?

<u>1 sp. (unconfirmed)</u>
IA - **Scaphoideus productus* Osborn - Ames (1977)
KY - **Scaphoideus anguis* Barnett - Henderson (1979)
ME - **Amplicephalus* sp. nov A - Franklin (1979)
NE - **Paraphlepsius exilis* Hamilton - Carns (1975)
NFLD - **Cosmotettix unica* Hamilton - Valleyfield (1987)
PA - **Eutettix* sp. nov. A - Clearville (1986)
TN - **Arundanus proprius* (DeLong) - Clarksville? (1941) on canebrake
YT - **Limotettix scudderi* Hamilton - Lapie Canyon (1995)

<u>1 sp. (confirmed)</u>
MD - *Limotettix minuendus* Hamilton - Beltsville & Wards Chapel MD on *Eleocharis tenuis*.
NH - *Psammotettix alexanderi* Greene - White Mts. [3 sites] (1971)

<u>2 spp. (100% unconfirmed)</u>
SD - **Gyponana compressa* DeLong - Brookings (1964)
**Laevicephalus tantalus* Knull - Badlands, Kimball & Phillip (1972)

2 LOCALIZED SPECIES?

<u>2 spp. (100% confirmed)</u>
GA - *Alapus angulatus* (Beamer & Tuthill) - Okefenokee Swamp (1934)
Pendarus crucifix Hamilton - Camp Stewart & Waycross (1975)

<u>3 spp. (33% confirmed)</u>
ALTA - **Idiocerus canae* Hamilton - Medicine Hat (1985)
**I. taiga* Hamilton - Galloway (1980)
Limotettix brooksi Hamilton - Black Foot Hills & Peace R.
QUE - *Deltocephalus* sp. nov. B - Louvricourt (1982)
**Scaphoideus flavidus* Barnett - Kazabazua (1979)
**S. incognitus* - Rigaud (1979)
NY - *Flexamia beameri* Whitcomb and Hicks - Otter Lk. (1946)
**Gyponana flavilineata* (Fitch) - [locality unknown] (1851)
**Scaphoideus rubranotum* DeLong - Ithaca (1977)
WI - *Scaphoideus pars* Barnett - Middleton (1979)
**Chlorotettix* sp. nov. A - Green Co. (1963)
**C.* sp. nov. B - Sawyer Co. (1966)
AK - **Cosmotettix* sp. nov. - Circle Hot Springs (1995)
Hebecephalus beameri Hamilton and Ross - 40 mi SE Fairbanks (1995)
**Macrosteles* sp. nov. B [ignarus Kwon] - Richardson Hwy. mi 240 (1988)

<u>3 spp. (unconfirmed)</u>
OH - **Gyponana contractura* DeLong - Columbus (1964)
**G. trigona* DeLong - Ross Co. (1964)
**Macropsis microceps* Hamilton - Pickaway Co. (1983)

3 LOCALIZED SPECIES?

<u>3 spp. (67% confirmed)</u>
NS - *Colladonus balius* Hamilton - Cape Breton Highlands Nt Pk. (1987)
Cribrus micmac Hamilton - Cape Breton Highlands Nt Pk. (1987)
**Idiocerus cabbottii* Hamilton - Cape Breton Highlands NtPk. (1985) on *Salix eriocephala*

<u>4 spp. (50% confirmed)</u>
MI - **Eutettix* sp. nov. B - Lincoln (1988)
Flexamia sp. nov. A [huroni Bess & Hamilton] - Ortonville on *Muhlenbergia richardsonis*.
Macrosteles n. sp. C - Quanicassee (1988)
**Scaphoideus multangulus* Barnett - E. Lansing (1979)

<u>4 spp. (25% confirmed)</u>
LA - *Deltanus bicolor Beamer* - Buras and Creole (1950)
**Sanctanus fusconotatus* (Osborn) - Cameron (1946)
**Tinobregmus invenustus* Lawson - Natchitoches Parish (1932)
**Xestocephalus trimaculatus* Peters - Beauregard Co. (1933)

Continued on next page

Table 2. continued

<u>5 spp. (20-40% confirmed)</u>

MS - *Chlorotettix dozieri* Sanders and DeLong - Helena (1922) on cypress shrubs
C. sinuosus Brown - Columbus (1933)
C. convexus Brown - Gulfport and Woodville (1933)
**Sanctanus eburneus* (DeLong) - Corinth (1924)
**Stirellus subnubilis* Knull - Hurley, Ocean Spgs. and Wade (1949)

SASK - **Cuerna nielsoni* Hamilton - Indian Head (1970)
**Deltocephalus* sp. nov. A
**Limotettix medleri* Hamilton - Hudson Bay (1995)
Hecalus sp. nov. - Grasslands NP (1996)
Memnonia sp. nov. A - Del Bonita and Manyberries (1995) on *Koeleria macrantha*

4 LOCALIZED SPECIES?

<u>5 spp. (60% confirmed)</u>

MAN - *Attenuipyga* sp. nov. - 3 sites.
**Cuerna fenestrella* Hamilton - Aweme, Camper, McMunn, Moosehorn and Ninette (1970)
**Flexamia [manitou]* sp. nov. B - Cowan & Gladstone (1958).
Macrosteles flavalis Hamilton - Brandon, Glenlea, Morden, Shilo and Winnipeg (1972)
M. sp. nov. D - The Narrows (1990).

5 LOCALIZED SPECIES?

<u>5 spp. (80% confirmed)</u>

KS - *Athysanella viridia* Osborn - Montgomery Co. (1990)
**Aligia modesta* (Osborn and Ball) - Douglas Co. (1942)
Hecalus hepneri (Beamer) - Garden City (1948) on *Calamovilfa longifolia*
Mesamia vermiculata Beamer - Cedarvale, Greenwood Co. and Ottawa (1942)
Phlepsanus tumidatus Crowder - Seward Co. (1952) on *Artemisia* sp.

<u>6 spp. (87% confirmed)</u>

MT - *Auridius cosmeticus* Hamilton - Conner, Lincoln, and 3 sites near Ovando
**Commellus semicolon* Hamilton - Bozeman (1995)
Errhomus bracatus Hamilton and Zack - Connor and Darby (1995) on balsamroot.
**E. camensis* Hamilton and Zack - Potomac (1996) on balsamroot.
E. rivalis Hamilton and Zack - Blue Mtn. W of Missoula (1993) on lupine.
Macrosteles skalkahiensis Beirne - Shalkaho Pass (1988)

6 LOCALIZED SPECIES?

<u>7 spp. (43% confirmed)</u>

IL - *Chlorotettix brevidus* DeLong - Oak Lawn, Thompson & Zion (1948)
**C. filamentus* DeLong - Havana & Marshall (1948)
C. obsenus DeLong - Ste. Anne & Zion (1948)
**Deltella ?decisus* [nec DeLong?] - Shawneetown & Vienna (1948)
**Idiocerus telus* DeLong & Hershberger - Pike (1948)
Laevicephalus pravus DeLong - Des Plaines & Hanover (1972)
**Paraphlepsius lupalus* Hamilton - Beach, Oak Lawn & Zion (1975).

<u>8 spp. (33-38% confirmed)</u>

NC - **Arundanus shermani* (Ball) - Raleigh (1941)
A. fastigatus DeLong - Carolina Beach and Wilmington (1941)
A. sarissus DeLong - Carolina Beach and Wilmington (1941)
**Chlorotettix aurum* DeLong - Carolina Beach (1938)
**Evacanthus chlamidatus* Hamilton - Roan Mt. (1983).
E. bellaustralis Hamilton - Gr. Smoky Mts. and Highlands (1983)
E. ustanucha Hamilton - Mt. Mitchell (and Chestnut Bald?)
**Scaphoideus nigricans* Osborn - Raleigh (1977)

UT - *Errhomus naomi* Hamilton and Zack - Zedd's Meadows (1992) on *Artemisia cana.*
**Ballana rara* DeLong - Kanab (1964)
**B. valga* DeLong - Provo (1964)
**Gyponana desa* DeLong - Hanksville (1964)
**Mocuellus* sp. nov. - Tabiona (1992)
Hebecephalus abies Hamilton - 41 km SW Duchesne, Mountain Home, Ouray, Tabiona (1992)
Laevicephalus salarius Knull - Bryce NtPk., Gr. Salt Lk., Marysville (1972)
**Telusus* sp. nov. B - Bicknell and Boulder (1986)

Table 2. continued

7 LOCALIZED SPECIES?

9 spp. (44% confirmed)

ON - **Amplicephalus* sp. nov. B - Lakeview (1977)
**Chlorotettix* sp. nov. C - Windsor (1995).
Colladonus sp. nov. A - Kirkwood Twnshp. (1963) on red pine
**Eutettix* sp. nov. C - One Sided Lk. (1960)
Laevicephalus sp. nov. - Sauble Beach on *Calamovilfa longifolia.*
Limotettix nigristriatus Hamilton - Savoff on *Eleocharis* sp.
Macrosteles sp. nov. E [denhollanderi Kwon] - Rutter (1988) on *Juncus* sp.
**M.* sp. nov. F [rotundicornis Kwon] - Guelph and Tory Hill (1988)
**Prairiana* sp. nov. - Ipperwash Beach (1995).

8 spp. (75% confirmed)

WY - *Athysanella foeda* Ball and Beamer - Laramie (1988)
**Colladonus* sp. nov. B - Sibley Lake Campgr. (1988)
Dicyphonia minuta Beamer - Laramie (1936)
Diplocolenus sp. nov. A - Alpine and Wilson (1992)
Hebecephalus filamentus Hamilton and Ross - Federal (1995)
H. chandleri Hamilton - Sibley Lake (1988)
**Norvellina curvata* Lindsay - Grand Teton NtPk. (1940)
Psammotettix viridinervis Ross and Hamilton - Laramie (1972)

8 LOCALIZED SPECIES?

9 spp. (67% confirmed)

WA - *Ceratagallia vipera* Hamilton - Rattlesnake Ridge (1995).
**Colladonus* sp. nov. D - Rattlesnake Ridge (1994).
Deltocephalus sp. nov. C - 43 km W Cliffdell, 28-37 km W Mazama and 32 km E Packwood (1985)
Errhomus paradoxus Oman - Maryhill (1987).
E. reflexus Oman - Ellensburg and Kittitas (1987)
E. satus Oman - Satus Pass (1987)
E. inconspicuus Hamilton and Zack - Rock Ck. Canyon (1992) on balsamroot.
E. picturatus Hamilton and Zack - Nason Creek campground (1990) on balsamroot.
**Limotettix zacki* Hamilton - Waterville (1994)

10 LOCALIZED SPECIES?

12 spp. (61% confirmed)

FL - *Cantura cocana* (Ball) - Cocoa and Sanford (1932)
Eutettix flavus Hepner - Likely, Lk. Jovita and Sanford (1942)
E. hibernus Hepner - Columbia Co., Grisdon, St. John Co. and Seminole Co. (1942)
**Gyponana gibbera* DeLong - Tampa (1964)
G. producta DeLong - Dade Co., Hilliard, Ocala NtFor., Sanford and Venice (1964)
**Memnonia* n. sp. B - Gainesville, Homestead and Princeton (1995)
**Pendarus likrois* Hamilton - Sanford (1975)
Polyamia lobata Beamer and Tuthill - Cocoanut Grove, Homestead and Orlando (1961)
P. nana Beamer and Tuthill - Hilliard, Ocala, Sanford and Waldo (1934)
Ponana rubrapuncta DeLong - Cleveland, Del Rey and Orlando (1942)
**Scaphytopius insolitus* Hepner - Sanford (1947)
**Xestocephalus robustus* Peters - Ft. Pierce (1933)

12 LOCALIZED SPECIES?

15 spp. (60% confirmed)

NV - *Athysanella ectopa* Blocker - Ormsby Co. (1990)
**A. aphoda* Bocker - Lander Co. (1988)
A. nata Blocker - Tempiute (1990) on *Hilaria jamesii*
A. tenera Ball and Beamer - Las Vegas (1988)
**A. whitcombi* Blocker - Austin (1988)
**Ballana aperta* DeLong - Deeth (1964)
B. calcara DeLong - Carlin and Dunphy (1964)
B. calcea DeLong - Bunkersville, Glendale and Mesquite (1964)
**B. telora* DeLong - Austin (1964)
Ceratagallia neodona Oman - Nixon (1939)
Hebecephalus irritus Beamer - Winnemucca (1936)
Idiocerus renoanus Ball and Parker - Reno (1946)

Table 2. continued

*Lycioides nevadus Ball - Mesquite (1931)
Spathanus excavatus Knull - Las Vegas (1949) on creosote bush
*Telusus saladurus Ball and DeLong - Wells (1926)

17 spp. (40% confirmed)

CO - *Athysanella curvata* Ball and Beamer - Little Beaver (1990)
A. dentata Ball and Beamer - Durango (1990)
**A. rotunda* Johnson - Durango (1990)
**A. senta* Blocker - Glen Cove (1988)
**Ballana transea* DeLong - ? (1964)
**Chlorotettix stolatus* Ball - Cimmaron (1900)
**Colladonus incertus* (Gillette and Baker) - Manitou (1957)
Deltocephalus mystax Hamilton and Ross - Climax and Gillett (1975)
**Eusora animana* (Ball) - Animas (1909)
**Hebecephalus circus* Hamilton and Ross - Lake George (1972)
H. vinculatus (Ball) - Corona Pass, Little Beaver and Mt. Evans (1961)
Idiodonus josea (Ball) - Alder, Dutch George's and North Park (1900)
**Limotettix strictus* Hamilton - LaPlatte (1994)
Lonatura punctifrons Beamer - Alma, Estes Park, Hinsdale Co., Lake City and Pingree Park (1967)
**Memnonia fraterna* Ball - Ft. Collins (1995)
**Neocoelidia bifida* DeLong - Old Baldy (1953)
Orocastus hyalinus (Beamer) - Creede and Paposa Spgs. (1938)

13 LOCALIZED SPECIES?

16 spp. (60% confirmed)

ID - *Athysanella nielsoni* Blocker - Osgood (1990)
A. n. sp. B - Tendoy (1995)
Ballana chrysothamna DeLong - Bruneare, Minidoka and Richfield (1964) on rabbitbrush
B. curvidens DeLong - American Falls, Craters of Moon, Minidoka and Richfield (1964)
B. fatuita DeLong - Arimo (1964)
**B. parallela* DeLong - Twin Falls (1964)
**B. profusa* DeLong - Carey (1964)
B. spinosa DeLong - Idaho City (1964)
**B. velosa* DeLong - Murtaugh (1964)
**Diplocolenus* sp. nov. B - Tendoy (1992)
**Hebecephalus crenulatus* Hamilton - Mud Lake (1992)
H. ferrumwquinum Hamilton - Railway Canyon (1992)
H. picea Hamilton - Mackay (1984)
H. pugnus Hamilton - Challis and Hamar (1992)
**H. veretillum* Hamilton - Ketcham (1992)
Rosenus obliquus (DeLong and Davidson) - 23 km SW Darlington*, Redfish Lk. and Stanley Basin (1992)

14 LOCALIZED SPECIES?

17 spp. (60-70% confirmed)

OR - *Athysanella expulsa* Blocker - Bend, Crook Co. and Prineville (1990)
A. valla Blocker - Mt. Ashland, Sams Valley and Siskiyou Pass (1990)
Auridius vitellinus Hamilton - LaPine and Silver Lake (1995)
**Ballana datuna* DeLong - Criterion (1964)
B. extera DeLong - Kerby (1964)
**B.ursina* (Ball) - Medford (1964)
**Ceratagallia* sp. nov. C [acerata] - Klamath Falls (1995)
C. clino Hamilton - Heppner and Sisters (1995)
C. lophia Hamilton - Jackass Mts. (1995).
Errhomus ochoco Oman - Mitchell (1991) on balsamroot.
E. pallidus Oman - Joseph and 8 mi E (1992) on *Potentilla gracilis*
E. winquatt Oman - Cherry Hgts., Rowena, Rowena Hgts. and The Dalles (1987)
Evacanthus lacunar Hamilton - Marys Peak (1983).
**Hebecephalus caecus* Beamer - Lapine (1936)
**Macrosteles* sp. nov. G [jungsukae Kwon] - Silver Lk. (1988)
M. sp. nov. H [oregonensis Kwon] - Green Lk. and Klamath Falls (1988)
Psammotettix emarginatus Greene - Klamath (1971)

BC - **Athysanella* n. sp. C - Similkameen Valley (1953)
**Ceratagallia okanagana* Hamilton - Osoyoos (1995)

Table 2. continued

**Colladonus* sp. nov. C - Carmanah Valley (1991)
**Destria* sp. nov. B - Sparwood (1985)
Elymana pacifica Hamilton: Fanny Bay, Oyster Bay, Saanich, Tsawwassen (1985) on *Scirpus* sp.
Hebecephalus planaria Hamilton - Douglas Lake (1987)
**Idiocerus glacialis Hamilton* - Glacier & and (1985) on *Salix sitchensis*
**I. indistinctus* Hamilton - Quilchena (1985) on *Salix lutea*
Latalus histrionicus Beirne - Bowser, Campbell R., Duncan and Victoria (1968)
Limotettix xanthus Hamilton - Revelstoke on *Juncus* spp.
L. obesura Hamilton - Ladysmith and Victoria
Macrosteles sp. nov. I [elegans Kwon] - Cranbrook (1988)
**Norvellina* sp. nov. - Victoria (1964)
Oncopsis ferrosa Hamilton - Brouse, Christina Lk., Creston and Sirdar (1983) on *Betula papyrifera*
Psammotettix beirnei Greene - 2 mts nr Revelstoke (1971)
P. sp. nov. - Bowser, Fanny Bay and Vancouver (1976) on *Agrostis palustris*
Rosenus decurvus Hamilton and Ross - Taylor

22 LOCALIZED SPECIES?

26 spp. (72% confirmed)

TX - **Athysanella apicala* Johnson - Valentine (1990)
A. catarma Bocker - Henly (Blanco Co.) (1990)
A. crispa Bocker - Brady (1990)
Flexamia texana Young and Beirne - Uvalde (1958)
F. banditaria Whitcomb and Hicks - Big Bend NtPk. and Marathon Basin (1988) on *Bouteloua curtipendula*
F. collorum Whitcomb and Hicks - Junction and Roosevelt (1988) on *Bouteloua uniflora*
F. zacate Whitcomb and Hicks - Big Bend NtPk. (1988) on *Muhlenbergia porteri*
Fridonus concanus Oman - Concan (1949) on bald cypress
**Gypona extrema* DeLong - Uvalde (1942)
G. mitana DeLong - Davis Mts. (1942)
Hamana manifesta DeLong - Confalon, Medina Co., Presidio and Val Verde Co. (1942)
Laevicephalus inconditus Knull - Chisos Mts., Culberson Co. and Davis Mts. (1972)
Macrosteles sp. nov. J [texanus Kwon] - College Station (1988)
Osbornellus ater Beamer - Cameron Co. and Rock Spgs. (1937)
**O. filamentus* DeLong and Beery - Davis Mts. (1937)
**O.* sp. nov. - Big Bend NtPk. (1959)
Pediopsoides davisi (Knull) - Davis Mts on *Salix* sp.
Planicephalus luteoapicalis (Beamer) - Elmendorf, George West, Peeler and San Antonio (1971)
Ponana cacozela (Gibson) - Brownsville, Cotulla, Davis Mts. and Uvalde (1942)
Scaphoideus lophus Barnett - Concan and Gillespie Co. (1977)
**Scaphytopius modicus* Hepner - Cameron (1947)
S. radiatus Hepner - Sinton* and Three Rivers (1947)
S. texanus DeLong - Brownsville, Concan and Progresso (1947)
**S. vittifrons* Hepner - Chisos Mts., Concan and El Paso Co. (1947)
**Texananus bialtus* DeLong - Davis Mts. (1952)

Table 3. Leafhopper species found in five or fewer sites in one state, territory, or province of North America, grouped by probable ecological fauna. Asterisk (*) denotes unconfirmed species (known from five or fewer specimens).

GREAT LAKES VICINITY: 6 spp. (33% confirmed) = probably **4 species**

ON - Ipperwash Beach: **Prairiana* sp. nov.
- Lakeview: **Amplicephalus* n. sp. B.
- Sauble Beach: *Laevicephalus* sp. nov.
- Windsor: **Chlorotettix* sp. nov. C.
MI - Quanicassee (1988): *Macrosteles* n. sp. C.
IL - Beach, Oak Lawn and Zion: **Paraphlepsius lupalus* Hamilton.

BOGS/SWAMPS/MARSHES: 6 spp. (67% confirmed) = probably **5 species**

GA - Okefenokee Swamp: *Alapus angulatus* (Beamer and Tuthill).
MI - Brandt Road Fen: *Flexamia* sp. nov. A.
NF - Valleyfield (1987): **Cosmotettix unica* Hamilton.
NC - Carolina Beach: **Chlorotettix aurum* DeLong.
- Carolina Beach and Wilmington: *Arundanus fastigatus* DeLong, *A. sarissus* DeLong.

Continued on next page

Table 3. continued

MOUNTAIN SUMMITS: 18 spp. (70% confirmed) = probably **16 species**

BC - Selkirk Mts.: *Psammotettix beirnei* Greene.
NS - Cape Breton Highlands:
Colladonus balius Hamilton
**Cribrus micmac* Hamilton
**Idiocerus cabbottii* Hamilton.
NH - White Mts.: *Psammotettix alexanderi* Greene.
NC - Mt. Mitchell and Chestnut Bald: *Evacanthus ustanucha* Hamilton.
- Roan Mt.: **Evacanthus chlamidatus* Hamilton.
MT - Sapphire Mts: *Macrosteles skalkahiensis* Beirne.
OR - Jackass Mts.: *Ceratagallia vipera* Hamilton.
- Marys Peak: *Evacanthus lacunar* Hamilton.
- Ochoco Summit: *Errhomus ochoco* Oman.
UT - Fish Lake Mts.: *Errhomus naomi* Hamilton and Zack.
WA - Cascade range: *Deltocephalus* sp. nov. C.
- Rattlesnake Ridge:
Ceratagallia vipera Hamilton
**Colladonus* sp. nov. D.
TX - Davis Mts:
Osbornellus filamentus DeLong and Beery
Pediopsoides davisi (Knull)
**Texananus bialtus* DeLong.

DRYLAND FORBS: 38 spp. (45% confirmed) = probably **30 species**

BC - *Ceratagallia okanagana* Hamilton.
Elymana pacifica Hamilton.
CO - **Ballana transea* DeLong.
**Eusora animana* (Ball).
ID.- *Ballana chrysothamna* DeLong, *curvidens* DeLong, *fatuita* DeLong, **parallela* DeLong, **profusa* DeLong, *spinosa* DeLong, **velosa* DeLong.
KS - *Phlepsanus tumidatus* Crowder.
MB - **Cuerna fenestrella* Hamilton.
NM - *Ballana flexa* DeLong, **nigridens* DeLong.
Cuerna alba Oman and Beamer.
MT - *Errhomus bracatus* Hamilton and Zack, *camensis* Hamilton and Zack, *rivalis* Hamilton and Zack.
NV - *Ballana* **aperta* DeLong, *calcara* DeLong, *calcea* DeLong, **telora* DeLong.
Ceratagallia neodona Oman.
**Lycioides nevadus* Ball.
**Spathanus excavatus* Knull.
OR - *Ceratagallia* sp. nov. *C, D.
Ballana **datuna* DeLong, *extera* DeLong, **ursina* (Ball).
Errhomus pallidus Oman, winquatt Oman.
SK - **Cuerna nielsoni* Hamilton.
UT - *Ballana* **rara* DeLong, **valga* DeLong.
WA - *Errhomus inconspicuus* Hamilton and Zack, *paradoxus* Oman, *picturatus* Hamilton and Zack, *reflexus* Oman.

GRASSLANDS: 100 spp. (63% confirmed) = probably 82 species

**Amplicephalus* n. sp. A.
Athysanella andyi Blocker, **aphoda* Bocker, **apicala* Johnson, *callida* Ball and Beamer, *catarma* Bocker, *crispa* Bocker, *curvata* Ball and Beamer, *dentata* Ball and Beamer, *ectopa* Blocker, *expulsa* Blocker, *falla* Blocker, *foeda* Ball and Beamer, **ladella* Johnson, *lunata* Ball and Beamer, *nata* Blocker, *nielsoni* Blocker, *parca* Ball and Beamer, *pastora* Blocker, **rotunda* Johnson, **senta* Blocker, *stylosa* Blocker, *tenera* Ball and Beamer, *valla* Blocker, *viridia* Osborn, **whitcombi* Blocker, spp. nov. B-*C.
Attenuipyga brevis (Beamer), sp. nov.
Auridius cosmeticus Hamilton, *A. vitellinus* Hamilton.
Chlorotettix brevidus DeLong, **convexus* Brown, *dozieri* Sanders and DeLong, **filamentus* DeLong, *obsenus* DeLong, **sinuosus* Brown, **stolatus* Ball, *sp. nov. C.
**Commellus semicolon* Hamilton.
**Cosmotettix unica* Hamilton, *sp. nov.
Deltanus bicolor Beamer.

Table 3. continued

**Deltella* sp. nov.
Deltocephalus mystax Hamilton and Ross.
**Destria* sp. nov. B.
Dicyphonia **conica* (Shaw), *minuta* Beamer.
Diplocolenus aquilonius Ross and Hamilton, sp. nov. A-*B.
Flexamia banditaria Whitcomb and Hicks, *beameri* Whitcomb and Hicks, *collorum* Whitcomb and Hicks, *[*manitou*] sp. nov. B, *texana* Young and Beirne, *zacate* Whitcomb and Hicks.
**Gillettiella fasciata* Ball and Beamer.
Hebecephalus beameri Hamilton and Ross, **borealis* DeLong and Davidson, **caecus* Beamer, **circus* Hamilton and Ross, **hilaris* Beamer, *irritus* Beamer, *filamentus* Hamilton and Ross, *vinculatus* (Ball), **vinculatus* [Beamer and Tuthill nec Ball], sp. nov. A-D, *E-*F, G-H.
Hecalus hepneri (Beamer).
Laevicephalus inconditus Knull, *pravus* DeLong, *salarius* Knull, **tantalus* Knull.
Latalus histrionicus Beirne.
Lonatura **delicata* Beamer, *punctifrons* Beamer.
Memnonia **fraterna* Ball, spp. nov. A, *B.
**Mocuellus* sp. nov.
Orocastus hyalinus (Beamer).
Psammotettix emarginatus Greene, viridinervis Ross and Hamilton.
Rosenus decurvus Hamilton and Ross, *obliquus* (DeLong and Davidson).
Telusus accuratus (Beamer), *neomexicanus* (Tuthill), **saladurus* (Ball and DeLong), *subitus* (Beamer), **vagus* (Beamer and Tuthill), *sp. nov. B.

OTHER: 94 spp. (44% confirmed) = probably **66 species**

**Aligia modesta* (Osborn and Ball).
Ankosus filamentus Oman.
Arundanus **proprius* (DeLong), **shermani* (Ball).
Cantura cocana (Ball).
Chlorotettix spp. nov. *A-*B.
Colladonus **incertus* (Gillette and Baker), sp. nov. A, *B-*C.
Deltocephalus sp. nov. B.
Eutettix flavus Hepner, *hibernus* Hepner, sp. nov. A-C.
Evacanthus bellaustralis Hamilton.
Fridonus concanus Oman.
Gypona **extrema* DeLong, *mitana* DeLong, **Gyponana compressa* DeLong, **contractura* DeLong, **desa* DeLong, **flavilineata* (Fitch), **gibbera* DeLong, *producta* DeLong, **trigona* DeLong.
Hamana manifesta DeLong.
Idiocerus **canae* Hamilton, **glacialis Hamilton*, **indistinctus* Hamilton, *renoanus* Ball and Parker, **taiga* Hamilton, **telus* DeLong and Hershberger.
Idiodonus josea (Ball).
Limotettix brooksi Hamilton, **medleri* Hamilton, *minuendus* Hamilton, *nigristriatus* Hamilton, *obesura* Hamilton, **scudderi* Hamilton, **strictus* Hamilton, *xanthus* Hamilton, **zacki* Hamilton.
**Macropsis microceps* Hamilton.
Macrosteles flavalis Hamilton, spp. nov. A, *B, D-E, *F-*G, H-J.
Mesamia infuscata Beamer, vermiculata Beamer.
**Neocoelidia bifida* DeLong.
Norvellina **curvata* Lindsay, *sp. nov.
Oncopsis ferrosa Hamilton.
Osbornellus ater Beamer, *sp. nov.
**Paraphlepsius exilis* Hamilton.
Pendarus **crucifix* Hamilton, **likrois* Hamilton.
Planicephalus luteoapicalis (Beamer).
**Platymetopius grandis* (Beamer).
Polyamia **grama* DeLong, *lobata* Beamer and Tuthill, *nana* Beamer and Tuthill.
Ponana cacozela (Gibson), *rubrapuncta* DeLong.
Psammotettix sp. nov.
Sanctanus **eburneus* (DeLong), **fusconotatus* (Osborn), *tectus* Oman.
Scaphoideus **anguis* Barnett, **flavidus* Barnett, **incognitus* Barnett, *lophus* Barnett, **multangulus* Barnett, **nigricans* Osborn, *pars* Barnett, **productus* Osborn, **rubranotum* DeLong.
Scaphytopius **insolitus* Hepner, **modicus* Hepner, *texanus* DeLong, **vittifrons* Hepner.
**Stirellus subnubilis* Knull.
**Texananus dicentrus* DeLong.
**Tinobregmus invenustus* Lawson.
Xestocephalus **robustus* Peters, **trimaculatus* Peters.

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MONITORING PALE CORYDALIS (*CORYDALIS FLAVULA*), A WINTER ANNUAL

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ABSTRACT: The woodland prairie species pale corydalis reaches its northern range limit in southwestern Lower Michigan where only eight occurrences of this winter annual are known in the state. This project involved the design of an appropriate monitoring plan for pale corydalis at Fort Custer Training Center where a significant population of this plant is about to be impacted. Several sampling methods were attempted including qualitative sampling, point-line intercept sampling, frequency sampling, and density sampling with belt transects. Of these, frequency sampling proved most efficient, requiring less than a day of sampling time to be 90% certain of detecting a 20% change in frequency. Density sampling was more time consuming with little gain in quality of information, while the point-line intercept sampling method was ineffective due to the extreme rarity of "hits." Qualitative sampling was useful as a general gauge of the status of outlying populations.

Key words: pale corydalis, *Corydalis flavula*, qualitative sampling, point-line intercept sampling, frequency sampling, density sampling, belt transects

INTRODUCTION

The woodland prairie species pale corydalis (*Corydalis flavula*), a winter annual, ranges from Connecticut south to North Carolina, occurring west to Nebraska, Kansas, and Oklahoma. Although demonstrably secure throughout most of its range (ranked G5 by The Nature Conservancy), it is considered rare in Connecticut, Delaware, Georgia, Nebraska, New York, Ontario, and Michigan where it is also somewhat disjunct from its main range. The results of a recent status survey in Michigan (Higman and Penskar 1995) indicate that there are eight known populations in the state, only three of which are comprised of numerous and apparently healthy individuals. One of these, the largest known population in Michigan, is located at Fort Custer Training Center (FCTC), a military training facility in the southwest portion (Kalamazoo County) of the state. This population is expected to experience a significant impact in the near future due to the construction of an armory on a portion of the site where it occurs. One condition, among others, conditions for granting a permit for the "taking" of this species is that FCTC develop and implement a monitoring and management plan for *C. flavula* to help ensure its survival (Weise 1995).

It is critical to be able to accurately assess the status of this plant at the FCTC in order to take appropriate action in the event that its populations decline significantly. Monitoring of biological populations is a tool which allows us to do this (TNC 1995). Since we are usually limited in time and resources with which to devise and implement monitoring, the level of effort and intensity of monitoring must be carefully considered and should correspond to the level of risk the populations face. The challenge, then, is to develop a monitoring plan that is time- and resource-efficient and that utilizes a sampling technique that will detect a biologically significant change in the population with enough certainty for management decisions to be made with confidence. This paper discusses the development of a such a monitoring plan for pale corydalis at FCTC. Three levels of monitoring are discussed and the results of several sampling techniques are compared.

METHODS

Existing data regarding C. flavula in general, and the specific population of concern at FCTC, were reviewed in order to determine the level of monitoring warranted. Level I monitoring, a qualitative evaluation of the population(s) in question, may be accomplished relatively quickly, and can provide information regarding the persistence of subpopulations as well as any obvious negative impacts that may be occurring. Level II monitoring is quantitative and involves the assessment of abundance or condition of the population. This allows for statistical analysis and can be designed to meet a specified detection sensitivity, power, and allowable percent Type I or α-error (detection of a change when one did not really occur) (TNC 1995). Level III (demographic monitoring) provides the most detailed information, but is also more time-intensive. Taking into account the resources available, the relatively secure global status of the species, the apparent vigor of the population under consideration, and the anticipated imminent impact, we decided it was most important to get a reliable, time-efficient, and easily accomplished monitoring plan in place quickly. Therefore, we conducted Level I and Level II monitoring at FCTC as quickly as possible. As more information regarding the population and the species in general accumulates, Level III monitoring can be reconsidered.

Level I (Qualitative) Monitoring

The portions of the armory site outside of the macroplot where Level II monitoring was to be conducted (see below) and the three other pale corydalis sites known at FCTC were traversed. Each was assessed qualitatively by noting presence or absence of the species, the general health of the population if present, and any other subjective observations of note.

Level II (Quantitative) Monitoring

In order to conduct Level II monitoring, a specific management objective was defined as follows: To be 90% certain of detecting a 20% difference in cover, density, or frequency of C. flavula between any two years for the next ten years. The acceptable chance that a significant change would be detected when it did not really occur (type I or α-error) was one in ten. The use of a 20% change as a marker for impact was chosen for several reasons. This is a number frequently used as a starting point in similar monitoring programs (TNC 1995), and is thought to be rather conservative since annual plants typically experience significant fluctuations in size at various life stages (Baskin and Baskin 1986, Menges and Gordon 1993, TNC 1995, Travis and Sutter 1986, Kalisz 1995). Additionally, the armory site population is a particularly large and vigorous one that is not threatened (Schemske et al. 1994, Thomas 1994). The use of 90% certainty is indicative of the desired power and acceptable chance of a Type II or β-error (missing a significant change when there really was one). In the case of rare populations, Type II errors are particularly important. A significant change in population status resulting from a negative impact that was not detected could mean a critical decline or even extinction of the population in question.

A complete count of seedlings present in the total population at the site was essentially impossible, due to the density of plants occurring there, thus a macroplot was used to define a sampling population. A 240-m X 40-m macroplot (Figure 1.) was located outside the area being impacted by construction. The size and location of the macroplot was chosen because 1) it appeared to harbor a healthy and representative component of the current population of pale corydalis and 2) it was easily accessed for sampling.

Since it was apparent that C. flavula was locally common, but distributed in patches throughout the macroplot, all attempted sampling techniques utilized transects spanning the 40-m width of the macroplot. The transects were initiated at randomly chosen points along the south baseline of the macroplot and projected northward through the macroplot. Sample plots of this configuration are more likely to capture the variation existing within a plant population than smaller, randomly located square quadrats, such as standard 1-m^2 quadrats used frequently in herbaceous vegetation sampling (TNC 1995). Three sampling methods were attempted and are described below. All formulae utilized for calculations are included in Appendix A.

Point-Line Intercept

Initially, the relatively time-efficient point-line intercept method to measure cover was conducted along several trial transects. However, despite the apparent high density of pale corydalis in the macroplot, the pointer rarely intercepted an individual due to the small size of seedlings. This sampling method was, therefore, abandoned.

Frequency Sampling

A second relatively time-efficient method, frequency sampling, was then tested along similarly placed transect lines. Each line was divided into four 10-m intervals and a random number from 1 to 10 was selected for each interval. A 1-m^2 quadrat with nested quadrats measuring 0.1 m^2 and 0.4^2 m was placed with its SW corner at the randomly selected point within each 10-m interval and with the west edge of the quadrat lying along the transect line. Presence or absence of *C. flavula* was recorded for the SW corner point and each successive size quadrat, and the frequency of presence was calculated for each. This sampling method proved to be relatively quick and easy, and initial frequency counts along several trial transects resulted in a frequency of 50% in the 0.4-m^2 quadrats, suggesting that with a sample size of 100, this would be an appropriate size quadrat to use to meet our monitoring objective (TNC 1995). The number of transects sampled was increased to 25, bringing the sample size to 100. A *post-hoc* power analysis was then conducted, and the total time required to complete the sampling was determined.

Belt Transects

Since our research conducted to date indicated that very little is known regarding the ecology of *C. flavula*, and since annual plants typically show significant fluctuations in numbers from year to year, we decided to attempt to obtain mean population density using belt transects and to estimate total population size as well. This would allow us to monitor by detecting change in density from year to year while at the same time providing potentially valuable information regarding yearly fluctuations in population size. A pilot study with a sample size of 15 was conducted and the required

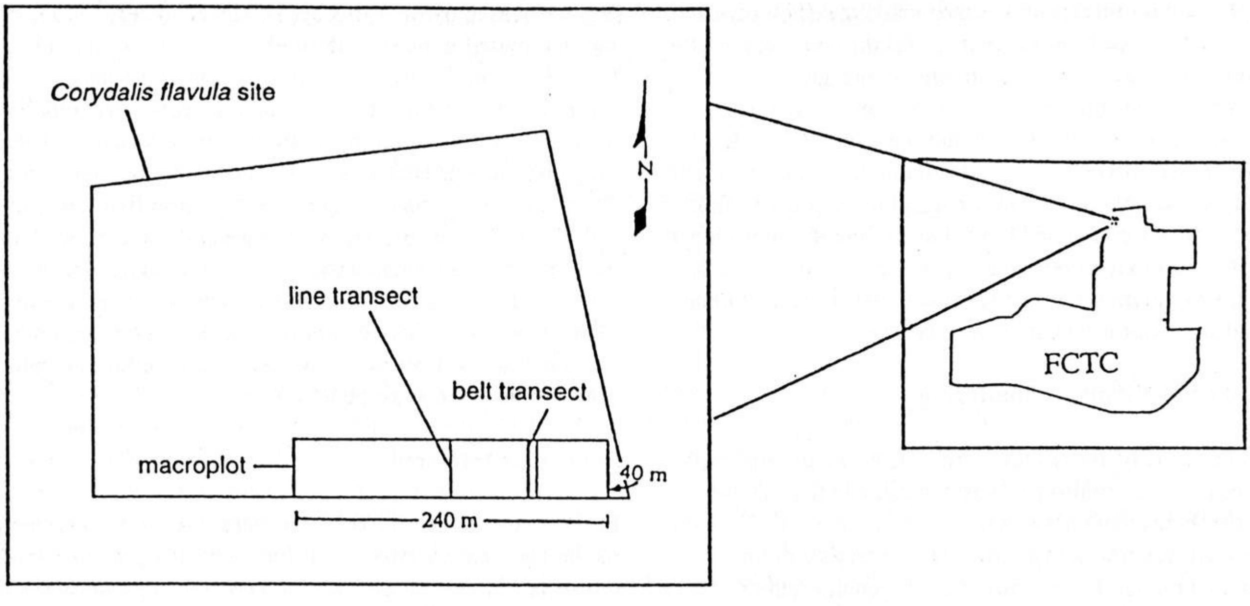

Figure 1. Diagramatic representation of the 240 X 40 m macroplot for *Corydalis flavula* at Fort Custer Training Center. Placement of line transect and belt transect shown within the plot.

sample size to detect a 20% change in mean population density with 90% certainty was then calculated. The total number of pale corydalis seedlings were counted in 15 0.33-m (1-ft) belt transects projecting eastward from 40-m north-south transect lines placed randomly as described above. Individuals were counted if any part of them was touching or within the transect boundary. Care was taken when laying down the lines to walk to the west of the line to avoid disturbing the plants within the transects. The required sample size determined from the pilot study was 34. Additional transects were sampled as time allowed and a post-hoc power analysis was then conducted. The total time utilized was noted and the average time required to sample one transect was calculated. Mean population density and total population size were also calculated as were confidence intervals for each with 90% and 95% certainty for both parameters.

RESULTS

Level I (Qualitative) Monitoring

Pale corydalis was vigorous and abundant in portions of the armory site outside of the macroplot. It was present and appeared healthy at all other FCTC locations, however it occurred in much smaller numbers. These observations were completed in four hours.

Level II (Quantitative) Monitoring

Point-line Intercept

There were only two "hits" along two transect lines and the time required to sample them was 45 minutes.

Frequency Plots

With the 0.4-m^2 quadrat, the necessary sample size required to be 90% certain of detecting an absolute change in frequency of 20% was 92 plots. It required eight hours to complete the frequency sampling.

Belt Transects

Due to time constraints, only ten additional quadrats were measured, bringing the total sample size to 25 and the total sampling time to 18.75 hours. The average sampling time per transect was .75 hrs. The *post-hoc* power analysis for the sample size of 25 indicated that we will be less than 80% certain of detecting a 20% change in mean density. In order to be 90% certain of detecting a 20% change in mean density as stated in the monitoring objective, we would have had to increase the sample size to 44. Solving for the percent change that is detectable with 90% certainty using our sample size of 25, resulted in a value of 26%. Thus, based upon this year's sample size of 25, we will be able to detect a 26-% change in mean population density with 90% certainty from 1995 to 1996.

Mean density for the sample population was 19.6 plants per m^2 and the total population size estimate (in macroplot) was 210,338 plants. With our sample size of 25 transects, we are 90% confident that our mean population density estimate was within 13% of the true value and 95% confident that our population size estimate was within 20% of its true value.

DISCUSSION

Table 1 below shows a comparison of the time required to conduct each sampling method attempted and the comparative value of each method. Qualitative sampling was the least time-consuming; however, it cannot be relied on to detect change at the level specified in the management objective. Qualitative data were also least likely to be consistent among different observers. They, therefore, serve only as a general gauge of the status of populations and sub-populations. Since more intensive Level II sampling will be ongoing in the population of concern at FCTC, and because little time is required to conduct qualitative sampling, ongoing qualitative sampling of the other populations at FCTC will be recommended. Observations of these populations may provide insights into environmental factors of concern for pale corydalis. These populations may someday be important as seed sources or recolonization sites.

The point-line intercept method was essentially useless for this species because the number of hits was so low and the time required to sample only two transects was considerable. This sampling method is more likely to be efficient for monitoring species that are larger in size or in populations where individuals occur in denser patches. This sampling method was abandoned.

Monitoring with belt transects did not meet our management objective of being 90% sure of detecting a 20% change in population density. It would require another 14.25 hours of sampling for a total of 33 hours to complete the 44 samples required. We were unwilling to decrease the acceptable power of our test because of the increased chance of committing a type-II error. However, perhaps we could consider accepting the detection of only a 26% change in density with 90% certainty that was accomplished with our sample size. It is possible that a 26% change in population density is still a conservative estimate of biologically significant change, since population density is known to fluctuate significantly in annual plants. The additional time required to reach even the 26% detection level, however, may be prohibitive if faced with typical budget constraints. Even if this detection level does serve as a satisfactory warning signal, and the population density and total population estimates are considered within acceptable confidence intervals, it is not clear whether measuring density and total population size for this population is actually necessary or beneficial. It is frequently mentioned in the literature that abundance is not necessarily a good indicator of population status and ability to persist (Baskin and Baskin 1986, TNC 1995). In the case of pale corydalis, where our research indicates that little is known regarding its basic biology and

Table 1. Comparison of sampling methods.

SAMPLING METHOD	TIME REQUIRED TO COMPLETE SAMPLING	VALUE OF SAMPLING METHOD
Qualitative Sampling	4 hours	indicates if sub-populations are being lost; alerts you to obvious negative impacts
Point-line intercept	45 min for two transects with only 2 hits	seedling size too small and patchy for efficient sampling
Frequency	8 hours	most cost effective; can detect a 20% change with 90% certainty
Belt transect	33 hours	not as cost effective to meet state management objective; can provide total population statistics

ecology, determining the effects of specific environmental parameters (i.e., moisture regime, soil type, sunlight, etc.) rather than focusing on total population statistics may be a more productive use of limited resources.

Frequency sampling was by far the most cost-effective method attempted. It could be completed in one day and was sensitive enough to meet the stated monitoring objective. This method was selected for continued monitoring of pale corydalis at FCTC. Although we feel confident that this method will sound the alarm if a significant decline in the population is occurring, we are still faced with a dilemma. The monitoring, which was implemented only to detect change, provides no guidance as to what to do if such a decline is detected; there is no link to the natural history and ecological requirements of the species. If appropriate management action(s) are not taken, then the monitoring, no matter how rigorous, will be to no avail. Therefore, we recommend that research of the basic life history requirements of pale corydalis be conducted concurrent with the on-going monitoring. Suggested areas of research include the role of light, impact of non-native, invasive species, and the determination of critical life stages.

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APPENDIX A

Sample Size Equations

The following equations utilized in this study were supplied at The Nature Conservancy Vegetation Monitoring Workshop (TNC 1995).

I. To determine the necessary sample size for detecting differences between two population density means (belt transects):

$$n = \frac{2(s)^2(Z_\alpha + Z_\beta)^2}{(MDC)^2}$$

where s = sample standard deviation, $\alpha = 0.1$ (10% type I error), $\beta = 0.1$ (90% certainty), Z_α, Z_β = the coefficients from the table of standard normal deviates, and MDC = minimal detectable change size (desired detectable change times sample mean).

II. To determine the necessary sample size for detecting differences between two proportions (frequency sampling):

$$n = \frac{(Z_\alpha + Z_\beta)^2 (p_1q_1 + p_2q_2)}{(p_2 - p_1)^2}$$

where α, β, Z_α and Z_β are the same as above and p_1 = the decimal value of the proportion (i.e, frequency of corydalis) for year one, p_2 = the decimal value of the proportion for year two, $q_1 = (1 - p_1)$, and $q_2 = (1 - p_2)$.

III. To determine the necessary sample size for estimating the mean population density with a specified level of precision:

$$n_m = \frac{(Z_\alpha)^2(s)^2}{(B)^2}$$

where $\alpha = 0.1$, Z_α = the coefficient from the table of standard deviates, s = standard deviation, and B = the desired precision level expressed as half of the maximum acceptable confidence interval width.

IV. To determine the necessary sample size for estimating total population size with a specified level of precision.

$$n = \frac{D^2}{(1 + (D^2/N))} \qquad \text{where } D = \frac{(N)(Z_\alpha)(s)}{(B)},$$

N = total number of possible quadrat locations in the population, $\alpha = 0.1$, Z_α = the coefficient from the table of standard normal deviates below, s = sample standard deviation, and B = the desired precision level expressed as half of the maximum acceptable confidence interval width.

TRILLIUM CERNUUM, THE REDISCOVERY OF THE SPECIES AND THE ECOLOGICAL RESTORATION OF ITS SURROUNDING HABITAT

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ABSTRACT: *Trillium cernuum* L., a state-endangered species, was believed to be extirpated from Illinois. It was discovered in the spring of 1995 in the Forest Preserve District of Cook County, in an area known as Thatcher Woods Glen. Many measures have been taken to protect this species and restore its habitat. The events leading up to the discovery and confirmation of this plant are a lesson for all conservationists.

Key words: *Trillium cernuum*, nodding trillium, Thatcher Woods Glen, Forest Preserve District of Cook County

INTRODUCTION

Trillium cernuum, also known as nodding trillium was identified in the spring of 1995. This plant is an Illinois state endangered species and prior to its discovery at our site was believed to be extirpated from Illinois. (Herkert 1991). This species is considered to be very rare in northeastern Illinois (Jones 1950, Pepoon 1927, Swink and Wilhelm 1994). So rare, in fact the last time it was seen in abundance was in 1900 at Wilson and Broadway in Chicago. (Pepoon 1927). This plant was found in the Forest Preserve District (FPD) of Cook County, in an area known as the Thatcher Woods Glen in the town of River Forest. It was found growing with pepperwort (*Dentaria laciniata*), trillium (*Trillium grandiflorum*), recurved trillium (*Trillium recurvatum*), yellow adder's tongue (*Erythronium americanum*), white dog-tooth violet (*Erythronium albidum*), Virginian waterleaf (*Hydrophyllum virginiatum*), wild leek (*Allium tricoccum*), rockcap fern (*Polypodium virginianum*), Mayapple (*Podophyllum peltatum*), and garlic mustard (*Alliaria petiolata*).

The habitat in which this plant was found is a mesic upland oak hickory forest dominated by white oak (*Quercus alba*), with red oak (*Quercus rubra*), black cherry (*Prunus serotina*), American elm (*Ulmus americana*), and red elm (*Ulmus rubra*) as subdominants. This area was historically one of the richest understories in Cook County.

History

Thatcher Woods Glen is a part of a much larger tract of property called Thatcher Woods acquired in 1917 by the Thatcher family. The 300-acre property neither was tilled nor grazed. The Thatcher family was quite wealthy and preferred to keep the land as an undisturbed forest. The two-acre plot of land in which the T. cernuum was found is directly south of a FPD visitor center known as Trailside Museum. To the west of this plot is an old oxbow of the Des Plaines River that was used as a borrow pit, and dammed at one side to produce a body of water for recreation. The development of this "pond" did not seem to disturb the soil in this site. Within the boundaries of this site exist two, possibly three, mounds believed to be of Native American origin. All indications show that no management activities had been carried out here until 1991. As a result of this lack of management, European buckthorn (*Rhamnus cathartica*), garlic mustard, *Euonymus* spp., and other invasive species took hold here.

Events Leading to the Discovery of *Trillium cernuum*

In the summer of 1991, the Forest Preserve District of Cook County sponsored the Youth Opportunity Corps (YOC). The YOC was a summer job program for minority youths from the city of Chicago. The YOC removed invasive shrubs and brush 30 feet in from the northern border of this site. Within two years there was a dramatic increase in native flora appearing in that area. This author observed an increase in native flora for three consecutive years, as well as a *Trillium* sp. that looked very different from other members of the genus. This author referred to a Peterson's Field Guide, and believed it to be *Trillium cernuum.* However, because Plants of the Chicago Region lists this species as very rare, this author doubted the assumption. An in-depth study of this area was not possible at that time.

In the early spring of 1995, a member of the Thatcher Woods Savanna Restoration Project told this author of Dr.

R. Krals siting of the rare *Trillium cernuum.* This plant was seen in 1940 somewhere in Thatcher Woods. However, this siting was unofficial, and the location of it was north of Thatcher Woods Glen. There was a strong possibility that the plant seen previously by this author was indeed *Trillium cernuum.* Coincidentally, plans were being made by Trailside Museum and the FPD to install a security fence and six to ten cages for mammals in the area where the species in question was located. Since this plot was only two acres, not much consideration was given to the importance of its understory. Development of the area would be detrimental to the understory, and no one would ever see such fine examples of native flora again.

Earth Day 1995 was to be the last wildflower walk led through this area before cage and fence construction began. Fifty-three people attended the walk, and witnessed the best show of spring ephemerals in over 60 years. One visitor asked, " Why is that orange marker there ?" The answer sparked a heated debate on whether or not to sacrifice a habitat remnant to build cages. One person from a certain citizen's group demanded the FPD transplant the wildflowers to another, "more suitable location," but that person was quickly told by the FPD Land Manager that it is impossible to transplant an ecosystem. The debate resolved that if the *Trillium* sp. was *Trillium cernuum*, a state endangered species, the cages could not be built. If, however, the *Trillium* sp. was *Trillium flexipes* or *Trillium grandiflorum*, the construction would resume.

T. cernuum and *T. flexipes* are fairly similar, and these plants have been known to confuse students of botany. (Swink and Wilhelm 1994) *T. cernuum*'s range differs from *T. flexipes*. The southern part of *T. cernuum*'s range comes down to only the most northern part of the Chicagoland area. *T. flexipes'* range covers most of the Chicagoland area. Due to the mostly northern range of *T. cernuum*, it blooms much later in the spring than other spring ephemerals. Another difference between the two species is the peduncles, *T. cernuum* is strongly deflexed, while the *T. flexipes* is horizontal to deflexed. A major difference between these species is determined by the length of its anthers. *Trillium cernuum's* anthers are less than 7 mm. long. It was impossible to take any measurements at that time due to the later blooming habits of this plant, but two days later the flower bloomed and the anthers measured 5 mm. Marlin Bowles and Dr. Gerould Wilhelm of the Morton Arboretum confirmed this identification, and thus one of the rarest flowers and one of the rarest ecosystems in Cook County was saved. At that time eight individual plants were observed, with one in bloom and one with an unopened bud. The six remaining were in a vegetative state.

Protection and Ecological Restoration Methods

The first task in protecting Trillium cernuum and the remnant habitat in which it resided was to build a split rail fence around the entire two-acre area. Volunteers supplied through Americorp installed the fence around all but the south end of the plot. The south end of this area was very degraded, and for many years it was a popular dump site for trash and hedge clippings. The fence could not be installed until the debris was removed. A "NO DUMPING" sign was installed at the site, but later was stolen. The remaining section of fence was installed in the summer of 1996 by Americorp. A foot trail at the north end of the plot was closed to foot traffic. Round stepping stones will be placed on this path for future guided tours.

Another immediate threat to the habitat is the large amount of garlic mustard. There were several times during that summer that this author, his coworkers, and local volunteers pulled this invasive species. Interns from The Nature Conservancy spent an afternoon pulling garlic mustard around the *Trillium cernuum* to ensure it would not be shaded or encroached upon further. It was hoped that a controlled burn would kill the remaining population of garlic mustard.

In December of 1995, a local Boy Scout troop removed a large amount of invasive shrubs from the understory. There was much care given to the preparation of this task. Orange marking paint was sprayed on several invasive shrubs, such as common buckthorn (*Rhamnus cathartica*), honeysuckle (*Lonicera* sp.), spindle-tree (*Euonymus* sp.), ash (*Fraxinus* sp.), and black cherry to identify the individuals for removal. This process started on the degraded south end working northward. The Boy Scouts removed 75% of the invasive species from the south end. The remaining invasive native and non-native shrubs will be controlled through prescribed burns in the future.

On March 23, 1996, a prescribed burn was conducted with the help of Thatcher Woods Savanna Restoration Project stewards. This area is difficult to burn as there are residential houses to the east and south, and Trailside Museum to the north. The only acceptable conditions for this burn was an east wind or a slight southeast wind. All smoke had to go over the Des Plaines River. There were no historical accounts of any fire activity in this area. It was assumed that this was the first fire in the area in over 100 years. The fire burned so hot, it melted an aluminum can in one end, and all lawn debris. The most notable effect of the fire was, all the garlic mustard was gone. Several weeks later, garlic mustard and other plants began to sprout again, but very little garlic mustard went to seed that summer. The publics' perception of the fire was favorable as well. Many people watched as the fire consumed years of accumulated leaf litter.

The following spring resulted in an overall increase in native flora. Virginia waterleaf carpeted the understory on the south end. *Trillium grandiflorum* doubled in population as did Dutchman's breeches (*Dicentra cucularia*). Wild geranium (*Geranium maculatum*) appeared in areas where it had never been seen before. One *Trillium cernuum* appeared on the south side of the plot. Eighteen *Trillium cernuum* plants were observed, with four in bloom, a marked increase from previous years. The results of the restoration efforts, especially the prescribed burn, led to the increase of native flora including *Trillium cernuum.*

CONCLUSIONS

This author believes that natural areas should be preserved from urbanization, regardless of the rarity of species within. *Trillium flexipes* is not an endangered species, but it is not so common that it should be overlooked, or the habitat in which it grows should not be sacrificed. Conservationists should not save habitats for endangered species alone. Common native species are important as well, especially when they are in a great abundance. Stewards of natural areas should not disregard a site with reference to its size. Stewards should carefully investigate the contents of a site and take into consideration what potential the site could have. After losing approximately 95% of native natural areas nationwide, and nearly all of Illinois' prairie land, not one acre of undeveloped habitat should be destroyed. Thatcher Woods Glen is less than five miles from the west side of Chicago. Inner city children can now view a state endangered species. They can, to some extant, get an idea of what the landscape in Chicago was once like. If they can learn that man has the abilities to improve life for residents of an ecosystem, they then can have hope of improving their own lives. It is easy to convince a biologist that ecological restoration is a worthwhile endeavor, but it is imperative to convince the public of the importance of this task. The two-acre plot in this paper held a piece of the puzzle to our natural heritage in Illinois. Fence lines, cemeteries, and edges of old fields can be tremendous resources for ecological restoration. Remember, good things do come in small packages.

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SAVANNA AND GLADE VEGETATION OF TURKEY MOUNTAIN, ARKANSAS: EFFECTS OF A SINGLE PRESCRIBED BURN

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ABSTRACT: On April 3–4, 1995, a prescribed burn was conducted at Turkey Mountain, Buffalo National River, Arkansas. This burn included five permanent plots that were originally established at the site in 1993. In August of 1995 we resampled the seedling, sapling, and overstory layers of these plots to determine how the woody vegetation responded to the early April fire. The burn had the greatest impact on the sapling layer (2.5 cm dbh; < 5 cm dbh). The mean percent of saplings that were dead per plot increased from 3 % in 1993 (prefire) to 73 % in 1995 (post-fire). Overall sapling density decreased by 54 %, with *Carya texana* (black hickory), *Quercus marilandica* (blackjack oak), *Quercus stellata* (post oak), and *Sassafras albidum* (sassafras) exhibiting the greatest overall reductions. Sapling species richness, evenness, and Shannon-Weiner diversity were all reduced by the fire. Tree density (woody stems (5 cm dbh) was also reduced, but importance value and basal area remained constant since most fire-killed trees were of small diameter. Overall, 92 % of fire-killed hardwood stems resprouted. The impact of the fire varied with topography and overstory vegetation. Sapling mortality was greatest on an upper shoulder-slope and a *Pinus echinata*- (shortleaf pine) dominated hollow. Burning was initiated at Turkey Mountain to reduce the basal area of *C. texana*, *Q. marilandica*, and *Juniperus virginiana* (eastern red cedar). While the fire greatly reduced the sapling and small-diameter tree density of these species, continued burning will be necessary to reduce basal area and maintain thc savanna complex.

Key words: prescribed fire, savanna, regeneration, mortality, species diversity, woody vegetation

INTRODUCTION

Oak systems in eastern North America have evolved under the influence of fire for thousands of years (Abrams 1992). Numerous workers have stated the importance of anthropogenic fire in maintaining savanna/barren mosaics in the Midwest, which in the absence of fire rapidly convert to forests (Gleason 1939, Cottam 1949, Nuzzo 1986, Tester 1989, Apfelbaum and Haney 1990, Anderson and Schwegman 1991, McClain et al. 1993, Taft et al. 1995 and many others). Several workers have concluded that in the absence of fire, Ozark savannas (Jenkins and Rebertus 1994, Guyette and Cutter 1991) and glades (Kucera and Martin 1957, Guyette and McGinnes 1982, Amelon 1991, Lowell and Astroth 1991, and Logan 1992) tend to undergo fairly rapid succession to more closed canopy conditions. These same workers all recommended fire as a method to reduce woody density and promote the herbaceous component in these areas. Therefore, fire was recommended as a management tool to restore and maintain glade and savanna vegetation at Turkey Mountain (Rebertus and Jenkins 1994).

During the summer of 1993 a vegetation survey of the savanna complex at Turkey Mountain was performed (Rebertus and Jenkins 1994). This study found that *Carya texana*, *Quercus stellata*, *Juniperus virginiana*, and *Quercus prinoides* (dwarf chinquapin oak) dominated the overstory. Government Land Office Survey notes from c. 1830 suggest that the area was historically dominated by *Quercus alba* (white oak), *Quercus stellata*, *Quercus velutina* (black oak), and *Carya* spp., with scattered *Pinus echinata* stands. True savanna with widely spaced trees was scattered throughout the area, but was not wide spread. The 1993 survey revealed that the understory strata were dominated by *Q. marilandica*, *C. texana*, *Q. stellata*, and *J. virginiana*. The encroachment of *J. virginiana* (on more alkaline sites) and *Q. marilandica* and *C. texana* (on more acidic sites) was viewed as the most serious threat to the glade and savanna flora (Rebertus and Jenkins 1994).

On April 3 and 4 of 1995, a controlled burn was conducted in part of the savanna complex. In this paper, we will examine two questions about the effects of this burn. First, how did the overall woody vegetation structure and composition of the savanna complex change as a result of the fire? Second, how did the topographic and vegetative characteristics of individual plots alter the response of woody vegetation to the fire?

METHODS

Study Area

Turkey Mountain is part of the Hathaway Wilderness Area of the Buffalo National River and is located near the junction of the Buffalo and White rivers in north-central Arkansas. The area is part of the Springfield Plateau geologic region and is underlain by complex strata of Ordovician limestone and sandstone. The area has a very rugged topography with frequent rock outcroppings and exposed strata. The flora of the area is very diverse. Rebertus and Jenkins (1994) reported 240 species from 18 500-m^2 plots on Turkey Mountain and nearby Granite Mountain (Cook Hollow). In addition, Logan (1992) reported 193 species on 42 glades located in the uplands along the Buffalo River.

The April 1995 controlled burn was conducted on a 168-ha unit consisting of the southern slope of the eastern half of Turkey Mountain. The controlled burn conducted in April 1995 included 5 of the 18 permanent plots established by Rebertus and Jenkins (1994, Figure 1). Four of these plots contained overstories dominated by oak species and one plot was dominated by shortleaf pine. In August 1995, a second survey was conducted to determine what effect this fire had on the woody vegetation of the burned plots.

Field Sampling

Eighteen 500-m^2 (20 m by 25 m) plots (0.9 ha total) originally established by Rebertus and Jenkins (1994) were resampled during August 14–22, 1995. These plots were located 100 m apart along transects running up-slope or were subjectively placed to include the representative vegetation communities of the area. Five of these 18 plots (Plots 1, 2, 3, 10 and 18) were within the area burned during April 1995 (Figure 1).

Woody vegetation was sampled with a nested plot design. All trees (5 cm dbh were tallied and dbh recorded within

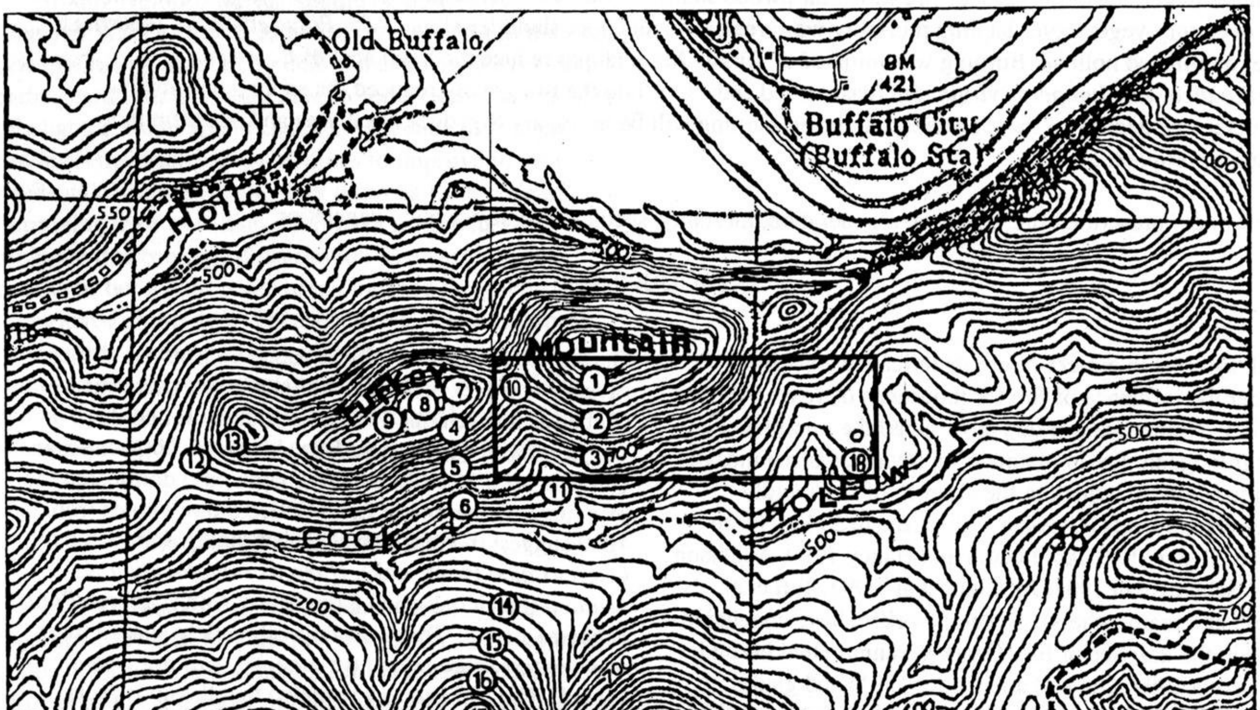

Figure 1. Topographic map of Turkey Mountain showing plot locations. Box delineates plots within the burn area (Plots 1, 2, 3, 10, and 18).

the 500-m^2 plots during both the 1993 and 1995 surveys. Saplings (stems > 2.5 cm dbh, but < 5 cm dbh) were tallied by species within two 100-m^2 plots during both surveys. Whether individual fire-killed trees or saplings resprouted was recorded. During the 1993 survey, large seedlings (> 0.5 m tall; < 2.5 cm dbh) and small seedlings (< 0.5 m tall) were tallied in two 10-m^2 and 1-m^2 plots, respectively. During the 1995 survey, large seedlings and small seedlings were both tallied in four 10-m^2 plots. The total seedling sample area was increased to improve accuracy of data collected in the 1995 and future surveys. All woody stems < 2.5 cm dbh were tallied as seedlings regardless of origin (sprout vs. germinated seed) or age.

Data Preparation and Analysis

The following parameters were calculated for woody vegetation on each plot at Turkey Mountain:

Trees:

Relative Density (RD) = Individual species density/total plot tree density *100

Relative Basal Area (RBA) = Individual tree species basal area/total plot basal area *100

Importance Value (IV) = (RD + RBA)/2

Seedlings and Saplings:

Relative Density (RD) = (density of regeneration species/total regeneration species density) * 100

Diversity indices: Species richness (S), Evenness (E) and Shannon-Wiener index (H', Shannon and Wiener 1963) were calculated for saplings and large seedlings.

S = total number of species on a plot
E = H/ lnS
H' = -sum (Pi * (ln(Pi))
Where: Pi = importance probability in element i (element i relativized by row total).

Paired t-tests and Mann-Whitney ranked sum tests (if data were not normally distributed) were used to compare changes in large seedling density, sapling density, tree density, diversity, and mortality between 1993 and 1995. However, since only 5 of the 18 plots were burned, the sample size (n=5) was too small to allow statistical comparisons in many cases. It should be noted, however, that a 100 % resampling of all tree dbhs was performed and sapling density was determined in 100-m^2 plots identically located in both surveys. Because of the drastic change in the total area sampled for small seedlings (2 m^2 vs. 40 m^2) between the two surveys, it is highly likely that any difference in density is due to increased sample area. Therefore, pre- and post-fire comparisons were not made for small seedlings.

RESULTS AND DISCUSSION

Trees

The 1995 fire had little effect on the overstory composition of the five burned plots (Table 1). Most dominant overstory species showed little change in importance value (IV). Only *Pinus echinata* exhibited a notable increase in IV, which resulted from a decrease in *Sassafras albidum* and *Quercus velutina* IV on Plot 18. These two species were present mostly in the smaller size classes on Plot 18 and were thus more prone to fire mortality. Heikens et al. (1994) also noted a reduction in *Q. velutina* IV following the burning of a chert savanna in southern Illinois.

While the fire had little effect on the IV, relative basal area (data not shown), relative density (data not shown), and basal area (BA, Table 2) of the five plots, it did have some effect on overall mean density (Table 3). Total mean density across all the plots decreased from 1164 stems/ha in 1993 to 980 stems/ha in 1995. Individual species exhibited small decreases in density. *Carya texana* mean density decreased from 292 stems/ha to 272 stems/ha (7%), *Quercus marilandica* decreased from 264 stems/ha to 236 stems/ha (11%), and *Quercus stellata* decreased from 216 stems/ha to 192 stems/ha (11%).

Tree species in the smaller diameter classes exhibited greater decreases in density. *Sassafras albidum* decreased from 40 stems/ha to 4 stems/ha (90%) and *Quercus velutina* decreased from 172 stems/ha to 120 stems/ha (30%). The fire had the greatest effect on the overstory structure of Plot 18 (a *Pinus echinata* stand), where the total density dropped from 1220 stems/ha to 700 stems/ha (43%). This large decrease in density may have resulted from the thick litter layer common in *P. echinata* stands providing higher fuel load than that on the other four plots. In addition, the dense *P. echinata* overstory may have prevented understory trees from reaching the canopy, making them more prone to mortality in a ground fire.

Saplings

The 1995 fire had its greatest effect on the sapling layer. Overall mean sapling density on the five burned plots decreased from 141 stems/ha to 64 stems/ha, a 54% reduction in sapling density (Table 4). This decline in mean density was most pronounced for *Sassafras albidum* (300 stems/ha to 80 stems/ha; 73%), *Carya texana* (370 stems/ha to 140 stems/ha; 62%), *Quercus stellata* (440 stems/ha to 230 stems/ha; 48 %), and *Quercus marilandica* (880 stems/ha to 490 stems/ha; 44%). Plots

Table 1 Tree (stems ≥ 5 cm dbh) species importance value on burned plots (numbers 1, 2, 3, 10, and 18) at Turkey Mountain, Buffalo National River, Arkansas. IV = (relative basal area + relative density)/2.

Species	Plot 1		Plot 2		Plot 3		Plot 10		Plot 18		MEAN	
	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995
Carya texana	24.8	26.5	34.4	34.9	16.8	15.2	30.9	38.6	8.4	7.8	23.1	24.6
Pinus echinata	2.8	3.1	0.0	0.0	0.0	0.0	0.0	0.0	68.0	87.1	14.2	18.0
Quercus alba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	1.7	0.4	0.4
Quercus marilandica	23.7	22.3	42.3	45.0	9.2	9.4	0.0	0.0	5.0	0.0	16.0	15.3
Quercus stellata	13.2	13.7	22.4	19.1	67.7	67.3	21.7	23.5	1.8	1.5	25.4	25.0
Quercus rubra	0.0	0.0	0.0	0.0	4.7	5.0	0.0	0.0	0.0	0.0	0.9	1.0
Quercus velutina	33.6	32.9	0.0	0.0	0.0	0.0	0.0	0.0	8.6	1.8	8.4	6.9
Quercus prinus	0.0	0.0	0.0	0.0	0.0	0.0	24.4	28.2	0.0	0.0	4.9	5.6
Sassafras albidum	2.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	1.7	0.2
Ulmus alata	0.0	0.0	1.0	1.1	1.6	1.6	8.2	4.9	0.0	0.0	2.2	1.5
Cotinus obovatus	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0	2.2	0.0
Fraxinus americana	0.0	0.0	0.0	0.0	0.0	0.0	3.7	4.8	0.0	0.0	0.7	1.0
Juniperus virginiana	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.3
Prunus spp.	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

Table 2. Tree (stems ≥ 5 cm dbh) species basal area per hectare on burned plots (numbers 1, 2, 3, 10, and 18) at Turkey Mountain, Buffalo National River, Arkansas.

Species	Plot 1		Plot 2		Plot 3		Plot 10		Plot 18		MEAN	
	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995
Carya texana	4.8	5.1	3.6	3.7	1.3	1.2	0.9	1.0	0.8	0.5	2.3	2.3
Pinus echinata	0.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0	33.3	36.6	6.8	7.5
Quercus alba	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	<0.1	0.1
Quercus marilandica	5.3	5.5	4.0	4.3	0.4	0.4	0.0	0.0	0.7	0.0	2.1	2.0
Quercus stellata	3.8	4.0	1.7	1.5	9.4	9.6	1.4	1.4	0.1	0.1	3.3	3.3
Quercus rubra	0.0	0.0	0.0	0.0	0.2	0.3	0.0	0.0	0.0	0.0	<0.1	0.1
Quercus velutina	5.9	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.3	1.3	1.3
Quercus prinus	0.0	0.0	0.0	0.0	0.0	0.0	1.2	1.2	0.0	0.0	0.2	0.2
Sassafras albidum	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.1	<0.1
Ulmus alata	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.1	0.0	0.0	0.1	<0.1
Cotinus obovatus	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	<0.1	0.0
Fraxinus americana	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Juniperus virginiana	0.0	0.0	0.0	0.0	<0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Prunus spp.	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL	20.6	21.7	9.4	9.5	11.3	11.5	3.9	3.8	36.3	37.7	16.2	16.8

Table 3. Tree (stems ≥ 5 cm dbh) species density per hectare on burned plots (numbers 1, 2, 3, 10, and 18) at Turkey Mountain, Buffalo National River, Arkansas.

Species	Plot 1		Plot 2		Plot 3		Plot 10		Plot 18		MEAN	
	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995
Carya texana	460	460	520	520	180	160	120	120	180	100	292	272
Pinus echinata	40	40	0	0	0	0	0	0	540	540	116	116
Quercus alba	0	0	0	0	0	0	0	0	40	20	8	4
Quercus marilandica	380	300	720	760	120	120	0	0	100	0	264	236
Quercus stellata	140	140	460	380	420	400	20	20	40	20	216	192
Quercus rubra	0	0	0	0	60	60	0	0	0	0	12	12
Quercus velutina	680	580	0	0	0	0	0	0	180	20	172	120
Quercus prinus	0	0	0	0	0	0	60	60	0	0	12	12
Sassafras albidum	60	20	0	0	0	0	0	0	140	0	40	4
Ulmus alata	0	0	20	20	20	20	40	20	0	0	16	12
Cotinus obovatus	0	0	0	0	0	0	60	0	0	0	12	0
Fraxinus americana	0	0	0	0	0	0	20	20	0	0	4	4
Juniperus virginiana	0	0	0	0	0	20	0	0	0	0	0	4
Prunus spp.	0	20	0	0	0	0	0	0	0	0	0	4
TOTAL	1760	1560	1720	1680	800	780	320	240	1220	700	1164	980

1 and 18 experienced the most drastic reductions in sapling density following the fire. Plot 1 (an upper shoulder slope area) had a post-fire mean sapling density of approximately 3 stems/ha while Plot 18 (a *Pinus echinata* stand) contained no living saplings following the fire. Changes in sapling mean RD generally mirrored changes in overall mean density (not shown).

The mean percent of saplings that were dead greatly increased following the fire. In 1993 only 3% of all stems on the five plots were dead, in 1995 this percentage increased to 73% (Table 5). A Mann-Whitney Rank sum test showed this difference to be highly significant ($T = 15.00$, $p = 0.008$), despite the small sample size ($n = 5$). Of the species with a high sapling density, *Carya texana*, *Quercus marilandica*, and *Quercus stellata* exhibited the greatest mean percent of saplings that were dead following the fire (68%, 56%, and 58%, respectively). The percent of *Juniperus virginiana* saplings that were dead increased from 0% in 1993 to 57% in 1995, although few living or dead *J. virginiana* saplings were found on the five plots.

The 1995 fire also decreased mean sapling richness (S), evenness (E), and Shannon-Wiener diversity (H') on the five plots (Table 6). Individual plots, however, exhibited varying trends in H' with two plots increasing (Plots 2 and 10) and three plots decreasing (1, 3, and 18). The 1995 fire had the greatest effect on the species S, E, and H' of Plots 1 and 18, both of which exhibited considerable reductions in all three indices. Post-fire changes in S, E, and H' were much less on the other three plots.

The high sapling mortality on Plot 1 and Plot 18 was probably due to intense fire caused by the landscape position of Plot 1 and the pyrogenic litter on Plot 18. The steep slopes and xeric exposure on which Plot 1 was located probably generated greater fire intensity and greater flame heights at upper slope positions due to preheating of fuels as the fire moved upslope (Guyette 1994). The pine litter on Plot 18 probably caused a rather hot fire due to the oleoresin content of the coarse woody debris and the thick needle layer.

Seedlings

The fire appears to have increased the overall mean density of large seedlings from 4.2 stems/10 m^2 in 1993 to 10.8 stems/10m^2 in 1995 (Table 7). This increase was statistically significant ($T = 2.297$, $p = 0.05$) according to a paired t-test. *Sassafras albidum*, whose regeneration is likely favored by fire, exhibited the greatest increase in both density (Table 7) and relative density (not shown). *Rhus aromatica* (aromatic sumac) and *Smilax bonanox* (green briar) also exhibited large increases in seedling relative density (data not shown). Like *S. albidum*, density of these two species often increases following disturbance. The higher density of large seedlings may also be a result of intense sprouting by fire-killed saplings; 92 % of all dead hardwood saplings resprouted. Like most other conifers, fire-killed *Juniperus virginiana* did not resprout. Of the *Quercus* species, *Quercus stellata* experienced the greatest decline in both seedling density and relative density.

Resprouting is a significant adaptive advantage for *Quercus*, *Carya*, and other hardwoods (Johnson 1993). Resprouts often grow faster then seedlings due to higher root:shoot ratio allowing for better resource allocation. (Johnson 1993, Jenkins and Rebertus 1994). Resprouting occurs from adventitious buds at the root collar, which is usually 2 to 3 cm below ground. The soil around the root collar acts as protective insulation from the heat of a ground fire.

Conclusions about changes in seedling density should be made with caution. Plot sample area for large seedlings increased from 20 m^2 in 1993 to 40 m^2 in 1995, which may have influenced measured seedling densities. Since the plot size for small seedlings in 1993 was much smaller (2 m^2) than that used in 1995 (40 m^2), comparisons of density between the two years are highly suspect and are not included in this paper.

CONCLUSIONS

Rebertus and Jenkins (1994) recommended that controlled burning be used at Turkey Mountain to, 1) reduce fuel loads; 2) gradually reduce the basal area of *Carya texana*, *Quercus marilandica*, and *Juniperus virginiana*; and 3) promote vegetation patchiness through large landscape burn units. The 1995 burn was a good first step to achieving these objectives. On-site observations suggest that the fuel load on the five plots was reduced greatly by the fire. While the one-time fire did not greatly reduce the overstory basal area of *C. texana*, *Q. marilandica*, or *J. virginiana*, it did greatly reduce the sapling densities of these species on the five plots. In addition, the density of small-diameter *C. texana* and *Q. marilandica* trees was reduced.

If controlled burns continue at Turkey Mountain, the desired reduction in basal area will likely occur with time (especially if burns are conducted after "leaf out" when the stems are actively photosynthesizing and transpiring). With continued burning, fewer trees from smaller cohorts will enter the larger size classes, thus reducing both basal area and density. While the burn reduced *Juniperus virginiana* density on the five plots, none of the plots had a very high *J. virginiana* density before the fire. This species does have a very high importance on plots not included in the burn area. The areas containing these plots may be good candidates for future burning.

Table 4. Sapling species density per hectare (stems ≥ 2.5 cm; < 5 cm dbh) on burned plots (numbers 1, 2, 3, 10, and 18) at Turkey Mountain, Buffalo National River, Arkansas.

Species	Plot 1		Plot 2		Plot 3		Plot 10		Plot 18		MEAN	
	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995
Carya texana	800	50	400	350	450	250	0	50	200	0	370	140
Quercus marilandica	500	0	3400	1900	350	550	0	0	150	0	880	490
Quercus stellata	250	0	200	50	1600	1100	0	0	150	0	440	230
Quercus velutina	500	0	0	0	0	0	0	0	100	0	120	0
Quercus prinoides	0	0	0	0	0	0	0	50	50	0	10	10
Sassafras albidum	900	0	300	400	0	0	0	0	300	0	300	80
Ulmus alata	0	0	50	50	350	350	0	50	50	0	90	90
Prunus spp.	50	0	50	50	0	0	0	0	0	0	20	10
Amelanchier arborea	50	0	50	0	0	0	0	0	0	0	20	0
Rhus glabra	0	0	0	0	0	0	0	0	50	0	10	0
Bumelia lanuginosa	0	0	0	0	50	0	0	0	0	0	10	0
Cornus drummundii	0	0	0	0	0	0	50	0	0	0	10	0
Viburnum rufidulum	0	0	0	200	350	0	0	50	0	0	70	50
Diospyros virginiana	0	0	0	50	100	50	0	0	0		20	20
Cotinus obovatus	0	0	0	0	0	0	400	0	0	0	80	0
Fraxinus americana	0	0	0	0	50	0	150	150	0	0	40	30
Juniperus virginiana	0	0	0	0	150	0	0	50	50	0	40	10
Pinus echinata	50	0	0	0	0	0	0	0	0	0	10	0
TOTAL	3100	50	4450	3050	3450	2300	600	400	1100	0	2540	1160

Table 5. Percent of dead saplings (≥ 2.5 cm dbh; < 5 cm dbh) by species on burned plots (numbers 1, 2, 3, 10, and 18) at Turkey Mountain, Buffalo National River, Arkansas.

Species	Plot 1		Plot 2		Plot 3		Plot 10		Plot 18		MEAN	
	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995
Bumelia lanuginosa	0	0	0	0	0	0	0	100	0	0	0	20
Carya texana	0	92	0	13	0	50	0	86	0	100	0	68
Cercis Canadensis	0	0	0	0	0	0	0	100	0	0	0	20
Cornus florida	0	0	0	0	0	0	0	100	0	0	0	20
Diospyros virginiana	0	0	0	100	0	50	0	0	0	0	0	30
Fraxinus americana	0	0	0	0	0	0	0	100	0	0	0	20
Juniperus virginana	0	100	0	0	0	86	0	100	0	0	0	57
Nyssa sylvatica	0	0	0	0	0	0	0	0	0	100	0	20
Prunus spp.	0	100	0	100	0	0	0	0	0	0	0	40
Quercus alba	0	0	0	0	0	0	0	0	0	100	0	20
Quercus marilandica	28	100	3	47	0	31	0	0	0	100	6	56
Quercus prinoides	0	0	0	0	0	0	0	100	25	100	5	40
Quercus stellata	17	100	0	75	0	14	0	0	0	100	3	58
Quercus velutina	9	100	0	0	0	0	0	0	0	100	2	40
Rhus aromatica	0	0	0	0	0	0	0	100	0	0	0	20
Sassafras albidum	0	100	0	43	0	0	0	0	0	100	0	49
Ulmus alata	0	0	0	0	0	53	0	67	0	100	0	44
Vaccinium pallidum	0	100	0	0	0	0	0	0	0	0	0	20
Crataegus spp.	0	100	0	0	0	0	0	0	0	0	0	20
Viburnum rufidulum	0	0	0	73	0	0	0	67	0	0	0	28
TOTAL	9	98	3	48	0	41	0	77	4	100	3	73

Continued burning will be needed to promote vegetation "patchiness" at Turkey Mountain. The effect of a single burn on a landscape is often ephemeral at best and a continued burning schedule is needed to have a long-term effect on the landscape. Continued burning will also be necessary to determine the long-term effect of fire on the area's species richness, evenness, and diversity. Burning schedules, both return interval and seasonal, should be somewhat variable to better maintain tree recruitment and favor a variety of herbaceous reproductive strategies (Rebertus and Jenkins 1994). Finally, continued monitoring of the 18 permanent plots is important in allowing managers to better understand the effects of fire on vegetation and adjust the controlled burning regime of the area.

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Table 6. Sapling (≥ 2.5 cm dbh; < 5 cm dbh) and large seedling (>0.5 m tall; < 2.5 cm dbh) species richness, evenness, and Shannon-Weiner diversity on burned plots (numbers 1, 2, 3, 10, and 18) at Turkey Mountain, Buffalo National River, Arkansas.

Plot	Parameter	Saplings		Large Seedlings	
		1993	1995	1993	1995
1	S	8	1	4	4
	E	0.82	0	1	0.77
	H'	1.70	0	1.39	1.06
2	S	7	8	4	5
	E	0.46	0.61	0.96	0.59
	H'	0.90	1.26	1.33	0.95
3	S	9	5	3	5
	E	0.77	0.81	0.63	0.66
	H'	1.68	1.31	0.69	1.06
10	S	3	6	2	10
	E	0.75	0.93	0.65	0.88
	H'	0.82	1.67	0.45	2.02
18	S	9	0	4	6
	E	0.91	0	0.74	0.72
	H'	1.99	0	1.03	1.29
MEAN	S	7	4	3	6
	E	0.74	0.47	0.80	0.77
	H'	1.42	.85	0.98	1.28

Table 7. Large seedling (>0.5 m tall; < 2.5 cm dbh) species density per 10 m^2 on burned plots (numbers 1, 2, 3, 10, and 18) at Turkey Mountain, Buffalo National River, Arkansas.

Species	PLOT 1		PLOT 2		PLOT 3		PLOT 10		PLOT 18		MEAN	
	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995
Carya texana	0.5	0.0	0.5	1.3	0.0	0.0	0.0	0.0	0.0	1.3	0.2	0.5
Quercus marilandica	0.0	0.3	1.0	2.3	0.0	0.3	0.0	0.0	0.0	0.0	0.2	0.6
Quercus stellata	0.5	0.0	0.0	0.0	5.0	5.0	0.0	0.5	0.0	0.0	1.1	1.1
Quercus velutina	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Quercus prinoides	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.0	0.1	0.1
Sassafras albidum	0.0	3.0	1.0	2.3	0.0	0.0	0.0	0.3	4.0	5.8	1.0	22.5
Ulmus alata	0.0	0.0	0.0	0.0	1.0	0.3	0.0	0.0	0.0	0.0	0.2	0.1
Robinia pseudoacacia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.2
Prunus spp.	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Amelanchier arborea	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Cornus florida	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.1
Rhus glabra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.2
Vaccinium stamineum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	3.5	0.1	0.7
Acacia angustissima	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.1
Passiflora lutea	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1
Rhus aromatica	0.0	0.0	0.0	14.8	0.0	2.8	0.0	1.0	0.0	0.0	0.0	3.7
Rosa carolina	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.1
Smilax bona-nox	0.0	0.0	0.0	0.0	0.0	4.8	0.0	2.5	0.0	0.3	0.0	1.5
Vaccinium pallidum	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Vitis spp.	0.0	1.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3
Bumelia lanuginosa	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.1	0.0
Chionanthus virginica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cornus drummundii	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.0	0.0	0.0	0.5	0.0
Nyssa sylvatica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.0	0.3	0.0
Viburnum rufidulum	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Diospyros virginiana	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.0	0.2
TOTAL	2.0	5.1	3.0	21.0	6.5	8.2	3.0	8.2	6.5	12.0	4.2	10.9

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BUILDING RELATIONSHIPS FOR ECOSYSTEM-BASED MANAGEMENT IN THE BITTERROOT NATIONAL FOREST, WESTERN MONTANA

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ABSTRACT: Long-term commitment to relationships is essential for success in ecosystem management. The Bitterroot Ecosystem Management/Research Project (BEMRP) is a partnership among scientists, managers, and citizens in the Bitterroot Valley of western Montana. BEMRP is studying and demonstrating ecosystem-based management in the Bitterroot National Forest, a complex of grassland, forest and alpine communities typical of forested wildlands in the northern Rocky Mountains. The Bitterroot ecosystem has been altered and degraded in many ways during the past century. Forest managers are challenged to protect species and structural diversity in the ecosystem while also providing commodities and other benefits to the public. BEMRP is addressing some of the management challenges in this ecosystem. To improve relations among partners and enable them to work together, scientists and managers participate in public meetings, field trips, and informational programs. Research has described the history of public involvement in the Forest Service and has evaluated the strengths and weaknesses of data describing public opinion. Studies currently under way are assessing the effectiveness of collaborative planning on the forest and the potential for improving public involvement using cooperative strategies. Dialogue among partners enables participants to integrate concepts, envision methods for restoring altered ecosystems, and carry out demonstration projects on the ground.

Key words: public involvement, communications, dialogue, ecosystem management

INTRODUCTION

Human needs and desires interact with complex, largely unknown natural processes to shape landscapes and communities, both human and biotic. Ecosystem-based management acknowledges the importance and ubiquitous influence of human demands on wildland ecosystems and insists that these demands be met in ways that maintain the ecosystem's capacity to function in perpetuity (Christensen et al. 1996). Ecosystems in the northern Rocky Mountains have changed rapidly during the past century in response to human demands for agricultural products, timber, and protection from fire. The Bitterroot Ecosystem Management/Research Project (BEMRP) demonstrates the dialogue among partners that forms an essential component of ecosystem-based management in the northern Rocky Mountains.

BEMRP was initiated in 1993 to predict landscape-level influences of vegetation management in a Rocky Mountain ecosystem and to demonstrate to the public the feasibility of landscape-level rehabilitation management (U.S. Department of Agriculture, Forest Service 1996). The project focuses on the Bitterroot National Forest (Figure 1), a complex of grassland, forest, and alpine communities shaped in past centuries by numerous disturbances, especially fire. Fire has, for the most part, been excluded from the forest for the past 80 to 100 years, and many large trees have been harvested (Carlson et al. 1994, Keane and Arno 1996, Stewart 1996). The potential for severe fire has increased at low elevations (Arno 1996), animal populations have been altered (Tewksbury et al. 1996), and landscape-level changes in vegetation patterns have occurred (Arno et al. 1993, Hartwell and Alaback 1996).

The human community in the Bitterroot Valley has changed just as dramatically as the ecosystem over the past century. The local economy has been mainly agricultural since the late 1800s, but it has changed

Figure 1. Location of the Bitterroot National Forest, focus of the Bitterroot Ecosystem Management/Research Project. Shaded areas represent the Stevensville West Central (SWC) and Stevensville Southwest (SSW) planning areas.

rapidly in recent years. The county population has grown 20% since 1990 (pers. comm., Hamilton Chamber of Commerce 1996) and population growth in the region may reach 50% over the next 25 years (McCool and Haynes 1996). Agricultural lands are being developed for residential and commercial uses.

The wood products industry, a cornerstone of the Bitterroot economy since the early 1900s, has also changed in recent decades. Forest management became highly controversial in the late 1960s, culminating in a report by a committee of University of Montana professors that severely criticized clearcutting and terracing practices on the Bitterroot National Forest (Bolle et al. 1970). Subsequent to this report, clearcutting was halted in the Bitterroots. Following forest staff changes in the early 1980s, however, clearcutting was resumed; this change was seen by many citizens as a breach of faith by the Forest Service. A second cessation of clearcutting was followed by major changes in the local wood products industry. National forest land once provided more than 80% of the timber for local mills; it now provides less than 25% (pers. comm., Charles Keegan 1996). Timber-related jobs in mills have decreased, although jobs have increased in the log home industry, which does not rely on local timber.

Managers in the Bitterroot National Forest initiated new approaches to public involvement in the early 1990s in response to the breakdown of relationships with local citizens and evidence that Bitterroot ecosystems were being altered beyond their capacity to function in perpetuity. Under the aegis of the "New Perspectives" program, scientists initiated projects to demonstrate the restoration of historic forest structures and understory fire to ponderosa pine (*Pinus ponderosa* Laws.) communities (Carlson et al. 1994). Since 1993, BEMRP has intensified efforts to integrate human dimensions into the management of this northern Rocky Mountain ecosystem. This paper describes insights gained through BEMRP endeavors in the following areas:

1. understanding the history of public involvement in the Forest Service;
2. assessing the current social context for ecosystem-based management (legal, institutional, and societal);
3. seeking ways to better integrate the public, land managers, and scientists in planning for the future of the forest; and
4. maintaining information flow among participants.

History of Public Involvement in the Forest Service

Effective plans for the future are best grounded in a careful examination of the past. During the first stages of BEMRP-sponsored research, while ecologists pursued clues to past conditions in the biota and natural processes in the Bitterroot, Gebhardt (1995) assessed the history of public involvement in the Forest Service.

Beginning in the 1940s, numerous federal statutes mandate involvement of the public in planning for management of federal lands. According to Gebhardt (1995), statutes mandating public involvement include the Administrative Procedures Act (APA) of 1946, the National Environmental Policy Act (NEPA) of 1968 and subsequent regulations written by the Council on Environmental Quality, the Federal Advisory Committee Act (FACA) of 1972, and the Forest and Rangeland Resources Planning Act (RPA) of 1974, which was amended by the National Forest Management Act (NFMA) of 1976. Techniques used for public involvement in Forest Service planning during the 1970s and 1980s were based primarily on obtaining public review of proposals rather than obtaining public input for planning. Because agency personnel invested considerable technical and scientific expertise in preparing proposals, this "conventional" approach to public involvement focused more on changing the public's mind about proposed actions than on using public input or responding to public concerns (Gebhardt 1995). Public involvement did not effectively inform managers about people's desires, nor did it empower citizens to participate effectively in problem solving (McCool and Asnor 1984).

The holistic philosophy of ecosystem-based management calls for better integration of the public in planning for the future of National Forest lands (Freimund 1996). A collaborative approach is congruent with this philosophy. Collaboration focuses on problem solving; all stakeholders are included, and all have access to the same information. Collaborative processes sometimes include facilitation by a neutral third party which enhances communications and ensures that discussions are held in a neutral environment. Since the early 1970s, resource management agencies have increasingly used collaborative approaches to public involvement (Gebhardt 1995). By 1984, collaborative methods had been used in more than 160 environmental policy disputes (Bingham 1986). Collaborative methods have generally contributed to improving relations between Forest Service managers and local citizens (Gebhardt 1995). However, some Agency policies and practices have limited the effectiveness of collaboration (Table 1). Awareness of these potential obstacles has been part of BEMRP's planning for public involvement.

The Social Context for Public Involvement: Current Conditions in the Agency and in the Bitterroot Valley

Natural resource planning has always required a realistic assessment of current conditions, social as well as ecological. Two recent studies shed light on present social realities: an assessment of the legal and institutional environment (sponsored by the Interior Columbia River Basin Ecosystem Management Project) and an examination of methods and results from two public opinion surveys (sponsored by BEMRP).

Schlager and Freimund (1994) interviewed 54 resource management professionals (from the Forest Service, other agencies, and the private sector) to identify barriers to ecosystem-based management that are embedded in two important human constructs: the law and the agencies themselves. Uncertainty regarding the definition of ecosystem management and agencies' commitment to it

Table 1. Positive and negative evaluations of collaborative decision-making in natural resource management. Adapted from Gebhardt (1995).

Positive evaluations: "the cup half full"	**Negative evaluations: "the cup half empty"**
Forest Service is authorized to use collaborative methods and staff are trained	Forest Service has not publicized successes of collaborative techniques, so staff are not encouraged to use them
Risk of judicial or Congressional intervention is often reduced, reducing time and cost over the long term	Collaborative techniques require more time invested in planning, which may discourage Agency participants and draw resources from other projects
Agencies usually include all parties involved	Incomplete understanding within the Agency may limit willingness to participate
Participants share most information willingly	Participants do not share information that they think can be used against them, indicating lack of trust in the process
Most participants willingly explore values underlying desired conditions	Agency representatives often substitute mandates for values statements
Where collaborative methods have been used, greater progress was made toward agreement or compromise than when conventional strategies were used	Forest Service officials have sometimes rejected a plan developed with collaborative methods

was a barrier mentioned by 63% of respondents (Table 2). Other barriers were related to the legislative framework for management of federal lands, agency culture and procedures, and relationships with the public. Interviewees offered numerous suggestions for overcoming barriers (Table 2). Changes seen as essential included alterations in institutional structures; changes in legislation, especially to reduce conflict among mandates, and improved dialogue with the public.

One important objective of ecosystem-based management is to better integrate the human community—the citizens that have economic and/or emotional ties to an area—in developing goals and planning projects (U.S. Department of Agriculture Forest Service 1993, Williams 1995). Managers need to understand the opinions expressed during the planning process and know how they represent the public's values and opinions. Freimund (1996) assessed the relative value of two information sources for

Table 2. Barriers to involving humans in ecosystem-based management and recommendations for addressing them (Schlager and Freimund 1994).

Barrier	Percentage of total respondents	Related recommendation(s)
Uncertainty about definition of and Agency commitment to ecosystem management	63	Establish clear agency goals
Federal Advisory Committee Act	46	Clarify implications; revise as appropriate
Lack of inter-organizational coordination	44	Improve communications; improve interagency working groups
Perceived threat to private interests	30	Increase & improve public involvement; increase some private rights or protections
Institutional culture	30	Integrate specialists from various disciplines; clarify priorities & change incentives
Institutional attitudes	26	Give priority to effective public involvement; change incentives
Institutional structure	26	Increase professional diversity within agency; improve communications; provide resources for public involvement
Difficulty of working with multiple publics	26	Increase & improve public involvement; empower participants
Budget structure	24	Reduce allocation of funds based mainly on timber management & fire control

understanding public opinion in the Bitterroot Valley: personal interviews of opinion leaders (Bitterroot Social Research Institute 1994) and a mail survey of a random sample of the population (Menning 1995). The two methods have different strengths, so they can complement each other. If managers talked only to opinion leaders, for example, they would not know about the citizens who are uninformed or without opinion (Freimund 1996). Opinions regarding prescribed fire illustrate this point. The population survey showed that about a third of residents had no opinion regarding increased use of prescribed fire. Opinion leaders, in contrast, expressed understanding of fire and its effects; they articulated clear reasons for their opinions and reservations regarding its use.

Surveys describe the prevalence of certain opinions in the general population, whereas interviews with opinion leaders can provide depth of understanding. According to

Table 2. cont'd.

Barrier	Percentage of total respondents	Related recommendation(s)
Convincing the public of necessity of ecosystem-based management	19	Increase & improve public involvement
Scattered land ownership patterns	15	Revise boundaries of administrative & management units; increase interagency communications, cooperation
Endangered Species Act	13	Revise as appropriate
National Environmental Policy Act	11	Include public early in planning process; embrace flexible philosophy; resolve conflicts
Ecological time frames	11	Establish clear agency goals but be flexible, able to respond
Managing expectations	9	Improve communications with public; increase public involvement
National Forest Management Act	7	Revise as appropriate; improve public involvement
Conflicting organic mandates among different agencies	6	Revise as appropriate; improve interagency cooperation; designate lead agency
Need for more, better monitoring	6	Improve monitoring; change allocation of agency funds
Constraints from federal air and water quality laws	4	Revise as appropriate; improve interagency working groups
Constraints from state laws	4	Revise as appropriate; improve interagency working groups

the general population survey, 70% to 80% of residents believe that the Bitterroot National Forest should provide a wide range of uses and benefits. Opinion leaders provided insights regarding this issue: interviewees oriented toward amenities from the forest voiced a desire for long-term benefits from the ecosystem, whereas commodity-oriented interviewees expressed concern about immediate economic effects of management actions. The comparison concludes, "If the goal of public involvement is to incorporate informed public opinion into the natural resource decision-making process, then more than one public involvement mechanism needs to be used to provide a more complete opportunity for participation and better representation of the human dimension" (Freimund 1996).

The human context for ecosystem-based management is unique in every community and is, like ecosystems, constantly changing. This does not mean that what is learned about human dimensions in one community cannot be applied to others at any other time. Public involvement can be guided by general principles. However, each new public involvement effort requires sensitivity to the unique aspects of the situation and the community.

Visions for the Future: Public Involvement for Ecosystem-based Management

BEMRP has assisted the Bitterroot National Forest in using collaborative techniques for involving the public in planning. In September 1992, just three months after ecosystem management became the official policy of the Forest Service, the Bitterroot National Forest invited the public to participate in planning for a 60,000-acre management area known as Stevensville Southwest (SSW) (Figure 1). This was the first step the Forest Service had taken since 1988 to improve relationships with citizens of the Bitterroot Valley, but the process made limited progress in improving dialogue and increasing the diversity of participants (Freimund 1996). About a year after SSW planning began, the forest began to plan for the Stevensville West Central area (SWC) (Figure 1). With support from ecologists, mathematicians, and other scientists in BEMRP, public participation was expanded. Forest staff included the public in developing a strategy for citizen participation; the process chosen was a collaborative model, as had been recommended in previous studies (Gebhardt 1995, McCoy et al. 1994, Schlager and Freimund 1994). The process included many opportunities for learning and discussion among participants (Table 3). To increase efficiency and ensure that all participants were heard, a neutral facilitator organized and ran the public meetings.

Freimund (1996) discusses the strengths and weaknesses of public involvement in the initial, somewhat conventional SSW public involvement effort and in the expanded, facilitated SWC effort. According to him, planning for SSW was a relatively brief process, with an environmental assessment (EA) released ten months after the first public meeting. The SSW process began improving relations with the interested public as well as developing a common understanding of ecosystem management, benefits inherited by the SWC planning effort. Planning for SWC included more participants and fostered improved communications. Numerous field trips, conducted throughout the planning process, generated common understandings of possible management actions. High visibility and frequent participation by research scientists indicated to many citizens that the agency was making decisions in the most informed way possible. The SWC planning process, however, was lengthy (more than two years elapsed between initial public meetings and release of the EA) and demanded "enormous commitment" from the public and Forest Service staff (Freimund 1996).

Researchers continue to evaluate the SWC planning process (Guthrie 1996), and they are seeking ways to improve on it for revising the forest management plan. A study currently underway (Richards 1996) is assessing the potential for established collaborative groups in the Bitterroot Valley region to serve as models for public involvement. Key ecological issues are common to many national forests. They include fire suppression and fire management, thinning and salvage sales, weed control and herbicide use, wildlife habitat, and road closures.

Enhancing Communications Among Partners

Information flow supports the human dimensions of ecosystem-based management like an aquifer supports a valley-bottom ecosystem. Information must be available to all partners without overwhelming them. Resource managers interviewed by Schlager and Freimund (1994) mentioned the need for improved communications at all organizational levels and among all groups of participants. BEMRP leaders strongly encouraged communications across disciplines and among managers, scientists, and the public. Information was also shared with other forests and with managers at the regional and national levels. Sharing of all information among all stakeholders indicated respect of participants for one another; it also reduced the risk that the process would be subverted by adherence to preconceived solutions, either by the agency or by other participants.

In the past two years, BEMRP participants have given presentations for national symposia on ecosystem management, the InterRegional Ecosystem Management team of the Forest Service, a regional evaluation team, the Bitterroot National Forest staff, and local meetings. Numerous field trips have been conducted at sites that demonstrate ecosystem-based management. Many

Table 3. Two successive public involvement efforts conducted on the Stevensville Ranger District, Bitterroot National Forest (Freimund 1996).

	Stevensville Southwest (SSW)	**Stevensville West Central (SWC)**
Analysis area (acres)	60,000	40,000
Process began	Sept. 1992	Jan. 1994
Meeting format	information dissemination	collaborative, facilitated
Number of regular public participants	14	15 - 20
Number of meetings	13	33
Number of field trips	2	5
Other activities	Open house; meetings with individual groups; presentations by specialists	Presentations by specialists, researchers, Regional Forester; meetings with individual groups; answering written questions & requests; pot luck
Environmental assessment (EA) released	June 1993	July 1996
Time used for EA preparation	10 months	31 months

members of the public and the local media are supportive of field trips (Freimund 1996), which provide the public with information about current conditions and potential management actions. Each trip is well staffed with managers and researchers who listen to suggestions of public participants and answer their questions. These informal discussions provide opportunities for participants to develop greater understanding of, and respect for, one another.

Other BEMRP communication efforts are designed to increase awareness and understanding of ecosystem-based management. An informational brochure highlights the philosophy and goals of ecosystem management; it has been distributed through local, regional, and national mailing lists. A nontechnical bulletin ("ECO-Report") describing project accomplishments is published annually and distributed to BEMRP participants, thousands of Forest Service employees throughout the U.S., and universities with resource management programs. A poster display describing potential benefits from ecosystem-based management has traveled to professional meetings, national offices, and community gatherings—including the local county fair. A videotape describing what has been learned in the SWC public involvement process is in preparation, and a homepage is available on the Internet (http://www.fs.fed.us/rm/ecopartner). BEMRP is cooperating with the University of Montana to develop a network of field sites as learning centers to increase public knowledge about ecosystems. Educational programs discussing fire in the ecosystem have been presented to more than 1000 elementary school students and teachers in the past year; development of hands-on materials for students is underway (Smith and McMurray 1996).

To enable scientists and managers to share their accomplishments and integrate information across disciplines, BEMRP has sponsored two formal workshops that were open to the public. At the most recent workshop, facilitated working groups addressed the following questions:

1. How do we assure ecological diversity?
2. What are acceptable management strategies to move toward restoring desired ecological patterns?

3. How do we best characterize coarse woody debris and snags on a coarse- filter basis over landscapes?

Discussion of these questions was summarized in "ECO-Report" and is being used to guide current research.

CONCLUSIONS

Effective public involvement is vital to successful, long-term ecosystem- based management (Freimund 1996). The Bitterroot Ecosystem Management Project demonstrates that improving public involvement requires understanding of past and current conditions in the human community, the agency, and the ecosystem. Public involvement is best pictured as a two-way learning process, with techniques modified from one project to the next for optimal use of participants' insights. Research and communications provide information and tools for integrating complex information across disciplines and among partners. Quality information—technical, social, and experiential—must be accessible to all participants. The more opportunity for dialogue, the better. The more opportunity for experiencing field conditions, the better. The values and needs of all participants must be acknowledged, and relationships among participants should be nurtured. Then, the partners in the human community—managers, scientists, and private citizens—can plan for the future, and plans developed collaboratively can be carried out. Success depends on the fulfillment of commitments made in the planning process.

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A NINE-YEAR ASSESSMENT OF SUCCESSIONAL TRENDS IN PRAIRIE PLANTINGS USING SEED BROADCAST AND SEEDLING TRANSPLANT METHODS

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ABSTRACT: A 0.63-ha clay and rubble area at College of DuPage was planted in 1984 with 28 prairie species using two restoration methods: seed broadcast and seedling transplant. The Wilhelm Assessment Method was used to compare vegetational changes for these two methods in the absence of weed removal for nine years. Burning was done on an annual basis beginning the fifth year. To record vegetational changes, plant species were identified and tallied along a 0.5-m- wide transect for 21 north-south lines. The transects were 10 m apart and varied in length from 3.8 m to 55.2 m. A seed broadcast area of 196.7 m^2 and a seedling transplant area of 42.7 m^2 were sampled for the first four years and during the eighth and ninth year. There was a slow and steady decline in number and percent coverage of weed species (numerical rating < 4) and an increase in the percent coverage of prairie species (numerical rating ≥ 4) for both methods of restoration. Nineteen (74%) weed species disappeared in the seedling transplant area, while 30 (68%) disappeared in the seed broadcast area. By the end of nine growing seasons, the rating index for the seedling transplant area increased from 20.10 to 29.10 while the seed broadcast area increased from 20.74 to 26.93; there was no significant difference ($p > 0.05$). The maximum ratings the plantings could have achieved were 29.71 for the seedling transplant area and 29.79 for the seed broadcast area, assuming no immigration from adjacent plantings or residual germination from a seed bank. Prairie species coverage increased from 26% to 52% in the seed broadcast area and from 28% to 63% in the seedling transplant area. Succession toward a prairie plant community can be achieved by either seed broadcast or seedling transplant methods.

Key words: vegetational changes, quantitative analyses, Wilhelm Assessment Method, numerical rating, rating index, progression, weed

INTRODUCTION

The re-establishment of prairie species by seeding or transplanting on areas where the original vegetation was completely removed has been accomplished in several areas of the U.S. Many researchers and restorationists have reported on the success of prairie plantings, beginning with the historic first planting of prairie at the University of Wisconsin Arboretum (Kirt 1992). Most assessment analyses of prairie restoration or reconstruction sites have been qualitative, that is, good or poor, and not in terms of consistent standards (see Harper 1983, Sperry 1983).

This study quantitatively compared the vegetational changes of a seed broadcast area with a seedling transplant area in the absence of weed removal for nine years and the absence of fire for the first four years. Annual burns began during the fifth year in spring 1988. Quantitative analyses were accomplished using the Wilhelm Assessment Method (Swink and Wilhelm 1994). These analyses can be used to set standards for assessments of future prairie plantings.

Site Location and Description of Study Area

The study site is immediately north of a marsh on the campus of the College of DuPage in Glen Ellyn, Illinois: SW of NE Quarter, Sections 26 and 27, Township 39, Range 10 in DuPage County, Illinois. The study area of 0.63 ha is roughly rectangular in shape (Figure 1). Approximately one-half of the site is bordered by thick stands of cattails (*Typha latifolia* and *T. angustifolia*) and sandbar willow (*Salix interior*) on the south side and lawn grass on the north side.

Prior to 1965, the study area was farmed. From 1965 to 1975 the area remained fallow. Twenty to 25 cm of gravel was spread on the area during 1975, and it served as a parking lot until 1984. During spring 1984, clay and rubble subsoil from a newly constructed complex on the College of DuPage campus was dumped on the study site and contoured from an elevation of 228.1 m to 230.1 m above sea level. The restoration area was then top-dressed with 7–10 cm of black soil from another construc-

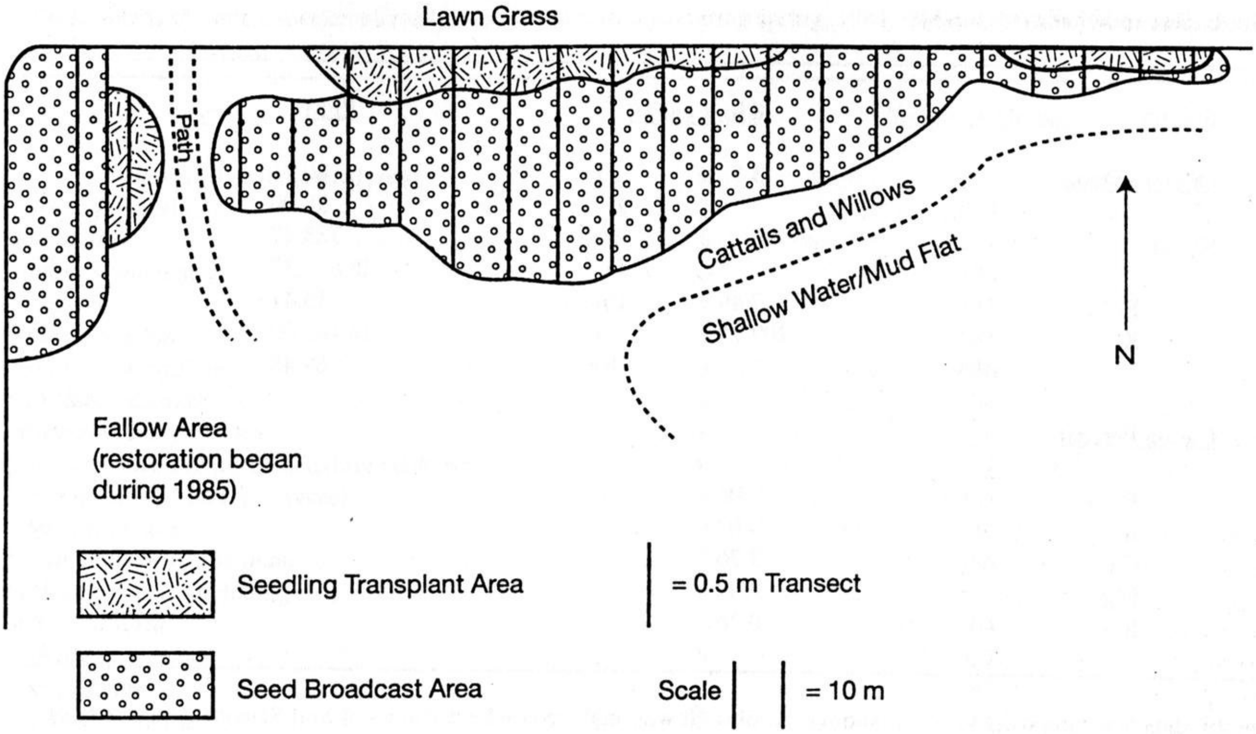

Figure 1. College of DuPage West Prairie-Marsh Nature Preserve.

tion site on campus. Soil, chemical, and structural characteristics of the site for 1987 are listed in Table 1.

MATERIALS AND METHODS

All seeds were collected during 1983 from sites within a 40-km radius of the College of DuPage to ensure local genotypes. They were kept in cold storage until early February 1984. The seeds were then stratified with fine damp sand and refrigerated at 4°C to duplicate winter conditions. Legumes were scarified and inoculated with their appropriate *Rhizobium*.

During early April 1984, seeds from 15 prairie species (Table 2) were planted into a 50/50 mixture of "Jiffy Mix" (Ball Seed Company) and sterilized black soil in the College of DuPage greenhouse. During early to mid-May 1984, the seedlings were transplanted to individual jiffy pots and, after a week, acclimatized outside in a semi-shaded area. During late May and early June 1984, the acclimatized seedlings were transplanted to the restoration site (Figure 1). The entire restoration site was disked to a depth of 5–8 cm to level off the soil and break up soil clumps prior to transplanting and seed broadcasting.

A mixture of 24 prairie species (Table 3) was broadcast adjacent to the seedling transplant area (Figure 1) from mid-May to early June 1984. Seeds were broadcast, lightly raked into the soil, and then compacted into the soil with a lawn roller that weighed 90 kg.

Oat and wheat straw was lightly scattered over both the seed broadcast and seedling transplant areas to conserve soil moisture and protect the seedlings from direct sunlight. Both areas were irrigated until 1 July 1984 whenever rainfall was insufficient.

For both planting methods, mesic-xeric species, such as lead plant (*Amorpha canescens*), were broadcast on the higher elevations and mesic-hydric species, such as prairie dock (*Silphium terebinthaceum*), on the lower elevations. Whenever possible, species associations as described by Swink and Wilhelm (1979) were planted together.

The choice of plantings was based on seed availability, seed germination and competitiveness (Schramm 1978, Schulenberg 1972), time and space available to grow and transplant seedlings, and overall aesthetics. Although different species were planted in each area, there was no significant difference ($p > 0.05$) in their average numerical rating ($X^2 = 0.273$: Goodness of Fit, Zar, 1984).

To record vegetational changes, 196.7 m^2 were sampled in the seed broadcast area and 42.7 m^2 were sampled in seedling transplant area. Plant species were identified and

Table 1. Site soil characteristics[1]

Soil ph	8.0		PPM
Organic Matter	3.57%	Zn	80.21
		B	58.00
Kg/ha		Mn	783.47
		Fe	28,627.33
P	7.49	Cu	15.41
K	207.76	Al	23,185.00
		Na	< 69.49
Cation Percent			
P	0.06		
K	0.60		
Ca	3.76		
Mg	2.30		
S	0.26		

[1]The soil data is a composite of three random samples. It was analyzed by Department of Soil Science, University of Wisconsin Extension, Madison, WI 53705-4364.

Table 2. Seedlings of prairie species planted in seedling transplant area during spring, 1984. Nomenclature is from Swink and Wilhelm (1994).

Species	Rating Index	Number of Seedlings
Amorpha canescens	9	144
Baptisia leucantha	8	72
B. leucophaea	10	144
Coreopsis palmata	6	357
Echinacea pallida	8	251
Eryngium yuccifolium	9	196
Liatris pycnostachya	8	306
Parthenium integrifolium	8	288
Penstemon digitalis	4	23
Petalostemum candidum	9	681
P. purpureum	9	144
Potentilla arguta	9	36
Solidago rigida	4	216
Sporobolus heterolepis	10	5,256
Verbena stricta	4	72
Total	115	

Average C (Coefficient of Conservatism) Value = 7.67

I (Rating Index) = 29.71

Table 3. Seeds of prairie species planted in seed broadcast area during spring, 1984. Nomenclature is from Swink and Wilhelm (1994).

Species	Rating Index	Weight in Grams
Amorpha canescens (including calyces)	9	863
Andropogon gerardii	5	7,037
A. scoparius	5	272
Coreopsis palmata	6	136
C. tripteris	5	341
Echinacea pallida	8	681
Eryngium yuccifolium	9	636
Lespedeza capitata	4	91
Parthenium integrifolium	8	318
Petalostemum candidum (including calyces)	9	182
P. purpureum (including calyces)	9	1,907
Potentilla arguta	9	36
Pycnanthemum virginianum	5	454
Ratibida pinnata (including calyces)	4	726
Rudbeckia hirta	1	204
Silphium laciniatum	5	1,907
S. perfoliatum	5	82
S. terebinthinaceum	5	341
Solidago rigida	4	772
Sorghastrum nutans	5	200
Spartina pectinata	4	590
Sporobolus heterolepis	10	341
Vernonia fasciculata	5	114
Veronicastrum virginicum	7	145

NOTE: *Monarda fistulosa* (Rating Index 4), *Panicum virgatum* (Rating Index 5), and *Penstemon digitalis* (Rating Index 4) were not knowingly included in the seed broadcast mixture.

Total
Average C (Coefficient of Conservatism) Value = 6.08
I (Rating Index) = 29.79

tallied along a 0.5-m-wide transect for 21 north-south lines during October from 1984 to 1987 and then during 1991–92 (Figure 1). Nomenclature is from Swink and Wilhelm (1994). Tillers were counted as one individual. The transects, 10 m apart and from 3.8 to 55.2 m in length, were permanently marked.

The analyses was completed from 1984 to 1987 and then during 1991–92 at the College of DuPage West Prairie-Marsh Nature Preserve in Glen Ellyn, DuPage County, IL. Quantitative analyses were accomplished using the Wilhelm Assessment Method (Swink and Wilhelm 1994). Wilhelm's method was used because terms such as "high quality" are nebulous, at best. One person's "significant" may be another's "exceptional" depending on different philosophical alignments or technical experiences in the field of natural area assessment (Wilhelm and Ladd 1988). Thus, repeatable application of such an assessment system is problematic. Wilhelm adopted an assessment method for the Chicago region that is based on a complete list of the Chicago region flora for each species to which a numerical rating has been assigned. These ratings identify each taxon's relative autecological value with respect to all other taxa in the flora (Swink and Wilhelm 1994). Then, based on autecological values for the species, a rating index for the community is generated as follows:

$$I = \frac{R}{\sqrt{N}},$$

where I = Rating Index
R = the sum of the numerical ratings for all taxa recorded for the area, and
N = the number of recorded taxa.

RESULTS AND DISCUSSION

Table 4 lists the plant species found growing in the seed broadcast area from 1984 to 1992. There were 28 prairie species present with a numerical rating of "4" or above (Table 4); of these 28 species, 23 were planted in 1984 (Table 3). Species with a numerical rating of "4" or above are considered native tallgrass prairie species that belong to the prairie community (Kirt 1995, Voigt and Mohlenbrock 1978). Plant species with a numerical rating of less than 4 are considered as weeds; that is, plants that thrive in disturbed and degraded areas and are not part of a stable ecosystem. Weeds can be native or non-native plants. The Rating Index from 1984 to 1992 increased from 20.74 to 26.93 (Figure 2). The maximum rating index that the seed broadcast area could have achieved was 29.79 according to the species planted (Table 3). This is without immigration from adjacent plantings or germination from a seed bank. After nine growing seasons, little bluestem (*Andropogon scoparius*) and Culver's root (*Veronicastrum virginicum*) were the only species found growing in this area that were not in the original species planting. Side-oats grama (*Bouteloua curtipendula*) from adjacent plantings established itself along the periphery of this area.

Weed species coverage in the seed broadcast area decreased from 74% to 56% from 1984 to 1987 and then to 48% in 1992; while the coverage of prairie species increased from 26% to 44% during the first four years and then to 52% in 1992 (Figure 3). Thirty weed species disappeared from the area (Table 4). Fire occurred on an annual basis beginning in spring 1988. The Rating Index increase and the decrease of weed species suggest that the seed broadcast restoration area is progressing toward prairie; but without species immigration or residual germination from a seed bank, the maximum rating index will remain at approximately 30 (Table 3). Immigration of species into the seed broadcast area is unlikely except along the periphery of the site; additional species establishment in the prairie is unlikely because the extensive root system of the prairie matrix.

Table 5 lists the plant species found growing in the seedling transplant area from 1984 to 1992. During 1992, 22 prairie species with a numerical rating of 4 or above were present in the seedling transplant area. Of these 22 species, big bluestem (*Andropogon gerardii*), heath aster (*Aster ericoides*), side-oats grama (*Bouteloua curtipendula*), tall coreopsis (*Coreopsis tripteris*), common mountain mint (*Pycnanthemum virginianum*), Indian grass (*Sorghastrum nutans*), and compass plant (*Silphium laciniatum*) germinated from the adjacent seed broadcast site and other subsequent plantings. The seedlings were planted 1 ft apart; their survival and mortality was not recorded. Spaces freed by plant mortality probably allowed for these additional species to become established. The Rating Index from 1984 to 1991 increased from 20.10 to 29.10 (Figure 4). The maximum rating index that the seedling transplant area could achieve is 29.71 (Table 2) without immigration of species from adjacent plantings and areas. It is unlikely that any prairie seeds were present in the clay and rubble.

Weed species coverage in the seedling transplant area decreased from 72% to 57% from 1984 to 1987 and then to 37% in 1992 while the coverage of prairie species increased from 28% to 43% during the first four years then to 63% in 1992 (Figure 5). Nineteen weed species disappeared from the area (Table 5). This increase in Rating Index and decrease of weed species suggests that the seedling transplant area is progressing toward prairie at a faster rate than the seed broadcast area during these first nine years. It is unclear as to why the percent of prairie species coverage is progressing faster in the seedling transplant area than in the seed broadcast area. Further study is necessary.

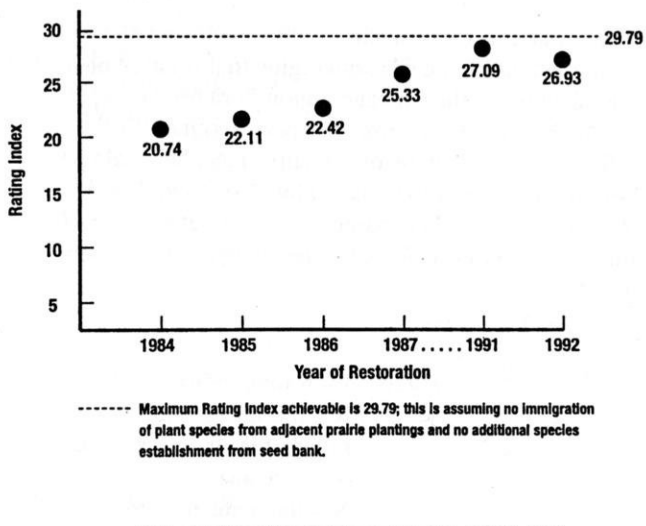

Figure 2. Rating index of seed broadcast area.

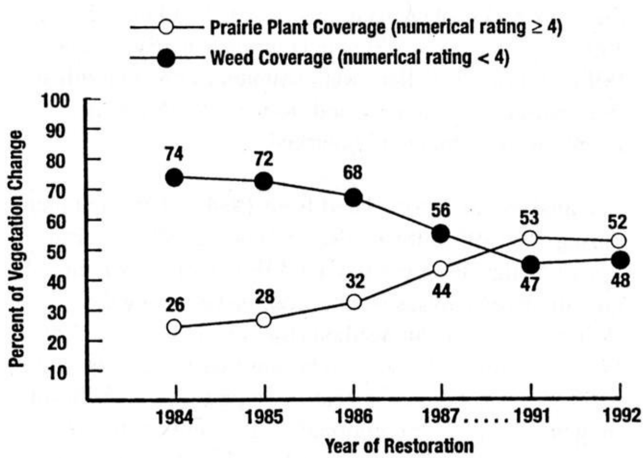

Figure 3. Percent of vegetation changes for plant species growing in seed broadcast area.

Table 4. Assignment of rating values and abundance of plant species in the seed broadcast area from 1984 to 1987 and 1991-92. Nomenclature is from Swink and Wilhelm (1994); italics (no underline) indicate introduced taxa.

Numerical Rating	Recorded Taxa	Number of Plants 1984	1985	1986	1987	1991	1992
	Abutilon theophrasti	110	109	3			
0	Acalypha rhomboidea	6	3	2	1		
	Agropyron repens	123	191	232	169	12	10
	Agrostis alba	13	5	2		4	4
	Amaranthus retroflexus	16		5			
0	Ambrosia artemisiifolia	193	1615	90	31	17	24
0	A. trifida	1	4	3	1		
9	Amorpha canescens	4	7	29	38	47	69
5	Andropogon gerardii	540	791	638	662	649	703
	Anthemis cotula		1				
	Arctium minus	5	5	2	3		1
5	Aster ericoides					1	
4	A. novae-angliae				3		
0	A. pilosus	9	98	379	329	72	88
	Atriplex patula	16	4				
	Avena sativa	298					
	Barbarea vulgaris	56	1				
1	Bidens sp.	4	1				
8	Bouteloua curtipendula					2	3
0	Brassica kaber	37					
	Bromus inermis		29	21			
	Cerastium vulgatum	12		8			
	Chenopodium album	284	107	1	1		
	Cichorium intybus	18	72	5	4		
	Cirsium arvense	63	166	191	158		1
	C. vulgare	17	23	23	10		
6	Coreopsis palmata	44	42	43	30	66	89
5	C. tripteris	281	313	218	172	164	184
1	Cyperus strigosus	302	76				
	Dactylis glomerata	2		7	9		
	Daucus carota	32	33	632	222	58	48
	Digitaria sanguinalis	127	16				
8	Echinacea pallida	98	103	86	61	44	42
0	Echinochloa crusgalli	252	6	3			
0	Erigeron annus						11
0	E. canadensis		43	9	1		
9	Eryngium yuccifolium	8	7	9	15	15	12
0	Euphorbia supina	33		8			
	Festuca elatior	20	24	4	5	1	
2	Helianthus grosseseratus		3	2			
	Hibiscus trionum	76	119	17			
	Hordeum jubatum	4	18	34	13		
	Lactuca serriola		10				
0	Lepidium virginicum	1	95	16			
4	Lespedeza capitata			1	1	1	1
	Lychnis alba		17				
	Malva neglecta					1	
	Melilotus sp.	7			2	5	4
	Medicago lupulina					8	3
4	Monarda fistulosa		1	3			
	Nepeta cataria	4	2			1	1

Continued on next page

Table 4 continued.

Numerical Rating	Recorded Taxa	1984	1985	1986	1987	1991	1992
		Number of Plants					
0	Oenothera biennis		1	1			
0	Oxalis stricta	21	44			3	5
1	Panicum capillare	40	5	2			
5	P. virgatum		4	8	3	6	6
8	Parthenium integrifolium	18	4	8	5		2
	Pastinaca sativa	18					
4	Penstemon digitalis				1	1	
9	Petalostemum candidum	62	57	45	67	51	43
9	P. purpureum	102	78	131	110	98	110
	Phleum pratense		4	6			8
	Plantago major	132	233	55	51	3	3
0	P. rugelii	19	5	6			
	Poa annua	13	2				
1	*P. pratensis*	108	267	204	180	79	62
0	Polygonum pensylvanicum	203	33				
2	Populus deltoides	24	6	3	4	1	1
9	Potentilla arguta	1	8	6	4	5	4
0	P. norvegica	13	28	4			
5	Pycnanthemum virginianum	6	5	2	2		1
4	Ratibida pinnata	496	573	314	254	253	238
4	Rorippa palustris fernaldiana	16					
1	Rudbeckia hirta	134	136	30	28		
	Rumex crispus	31	44	13	6	1	
1	Salix interior	10	8	9	7	14	27
	Setaria faberi	116	11	1			
	S. glauca	299	38	4	2		
	S. viridis 137	113	4	2			
5	Silphium laciniatum	192	196	161	173	209	171
5	S. perfoliatum	19	18	28	13	9	6
5	S. terebinthinaceum					2	2
0	Solanum americanum	15		3			
1	Solidago altissima	7	2	15	56	98	59
4	S. rigida	77	96	165	185	238	359
	Sonchus uliginosus	10	48	1	1		
5	Sorghastrum nutans	24	41	51	58	52	56
4	Spartina pectinata	7	9	8	7	13	15
10	Sporobolus heterolepis	1	2	1	1	5	7
	Taraxacum officinale	309	145	119	19	13	4
	Trifolium hybridum	37	47	9	5	5	16
	T. pratense	44	36	12	2	1	
	T. repens 52	31	90	1			
5	Vernonia fasciculata					1	
	Xanthium americanum	1	1				
T	(Total)	131	138	140	141	146	145
N_1	(Number of Species)	72	72	66	50	43	42
N_2	(Number of Native Species)	40	39	39	31	29	29
C	(Mean C Value)	3.28	3.54	3.59	4.55	5.03	5.00
I	(Rating Index)	20.74	22.11	22.42	25.33	27.09	26.93

* no numerical rating

Table 5. Assignment of rating values and abundance of plant species in the seedling transplant area from 1984 to 1987 and 1991-92. Nomenclature is from Swink and Wilhelm (1994); italics (no underline) indicate introduced taxa. .

Numerical Rating	Recorded Taxa	Number of Plants 1984	1985	1986	1987	1991	1992
	Abutilon theophrasti	21	40	3			
0	Acalypha rhomboidea		1				
	Agropyron repens	7	31	29	13	11	12
	Amaranthus retroflexus	8					
0	Ambrosia artemisiifolia	23	428	85	22	3	3
9	Amorpha canescens		3	2	6	4	6
5	Andropogon gerardii	3	5	1	1	3	4
	Anthemis cotula			1			
	Arctium minus	1	3	2	4		
0	Atriplex patula	3	5				
5	Aster ericoides					2	2
4	Aster novae-angliae				1		
9	Aster laevis					1	
0	A. pilosus		4	30	65	30	7
	Avena sativa	59					
8	Baptisia leucantha		3	3	3	1	1
10	B. leucophaea		1	3	5	7	6
	Barbarea vulgaris	14	1				
8	Bouteloua curtipendula						2
0	Brassica kaber	5	1				
	Cerastium vulgatum	8					
	Chenopodium album	89	17				
	Cichorium intybus		8	9			
	Cirsium arvense	9	16	56	48		1
	C. vulgare	1	9	46	14		
6	Coreopsis palmata	3	10	17	24	36	41
5	C. tripteris		1	1	1		1
1	Cyperus strigosus	26					
	Dactylis glomerata	1					
	Daucus carota	8	16	267	122	3	6
8	Echinacea pallida	17	17	18	17	8	7
0	Echinochloa crusgalli	36	2				
0	Erigeron canadensis		9	6	2		
9	Eryngium yuccifolium	7	9	5	6	4	4
0	Euphorbia supina	5					
	Festuca elatior	3	2	3	1		
2	Helianthus grosseseratus	3					
	Hibiscus trionum	10	14	3			
	Hordeum jubatum		5	23	9		
	Lactuca serriola		1				
0	Lepidium virginicum	1	2	2			
8	Liatris pycnostachya		8	1	2		
	Lychnis alba				1		
	Medicago lupulina					1	
	Melilotus sp.	1	1	1		3	2
0	Oxalis stricta	1	4	4			
0	Oenothera biennis			3	4		
8	Parthenium integrifolium	7	4	6	5	3	3
4	Penstemon digitalis		2	2	1		2
9	Petalostemum candidum	14	15	18	26	31	45
9	P. purpureum	6	14	18	23	46	41

Continued on next page

Table 5 continued.

		Number of Plants					
Numerical Rating	Recorded Taxa	1984	1985	1986	1987	1991	1992
Phleum pratense		1					
	Plantago major	8	14	6	18	1	
0	Physalis subglabrata					1	2
0	Plantago rugelii	2	3				
	Poa pratensis	10	9	4		12	10
0	Polygonum pensylvanicum	11	5				
2	Populus deltoides	11	3	3	1		
9	Potentilla arguta	8	6	6	7	10	10
0	P. norvegica	3	2	2			
5	Pycnanthemum virginianum						1
4	Ratibida pinnata	3	1		13	10	
4	Rorippa palustris fernaldiana	2					
1	Rudbeckia hirta	1	1	13	4		
	Rumex crispus	6	6	8	7		1
1	Salix interior					1	1
	Setaria faberi	19		2			
	S. glauca 61	33	6				
	S. viridis 15	49	12	1			
5	Silphium laciniatum	1	3	1	1	9	14
0	Solanum americanum	7	1				
1	Solidago altissima			10	11	16	17
4	S. rigida 17	10	29	45	79	120	
	Sonchus uliginosus	3	53	15			
5	Sorghastrum nutans					1	2
10	Sporobolus heterolepis	155	196	203	189	188	188
	Taraxacum officinale	108	42	79	7	1	5
	Trifolium hybridum	12	12	8	2		6
	T. pratense	4	8	4	2		
	T. repens 11	7	58	9			
	Verbascum thaspus	4	4	2	1		
4	Verbena stricta	1	1	1	1	1	2
	Xanthium americanum				2		
T	(Total)	110	137	134	138	138	151
N_1	(Number of Species)	54	58	52	42	31	35
N_2	(Number of Native Species)	30	34	28	26	24	27
C	(Mean C Value)	3.67	4.03	4.79	5.31	5.75	5.60
I	(Rating Index)	20.10	23.50	25.35	27.08	28.1	29.10

Seeds of *A. gerardii*, *C. tripteris*, *R. pinnata*, *R. hirta*, and *S. laciniatum* from seed broadcast mixture became established in seedling transplant area.

* no numerical rating

There was a slow but steady decline of weed species and consistent increase in coverage of native prairie species for both the seed broadcast and seedling transplant areas during the first nine years of assessment (Figures 3 and 5). Weeds occurred spontaneously from the 7–10 cm of black soil used to top-dress the area, from the clay and rubble subsoil, from the adjacent marsh vegetation area, and from the oat and wheat straw mulch that was scattered on both the broadcast and transplant areas.

There was no weed removal in these areas; burning began in 1988. It appears that burning was at least partly responsible for eliminating eight non-conservative species in the seed broadcast area (Table 4) and seven non-conservative species in the seedling transplant area (Table 5). Most of the weeds still present in both sites are growing along the periphery. In both planting sites, the population of stiff goldenrod (*Solidago rigida)* increased due to its establishment into previously unoccupied areas (Tables 4 and 5).

Discussions and conclusions drawn from this data may be applicable to future prairie planting assessments on clay and rubble subsoil with a minimum of black top soil. The performance standard of a reconstruction project probably

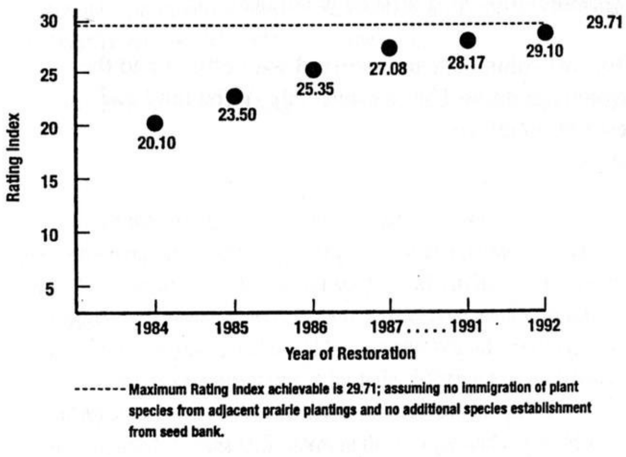

Figure 4. Rating index of seedling transplant area.

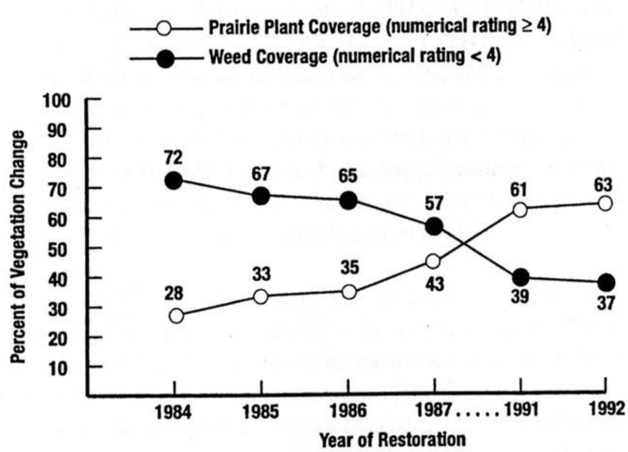

Figure 5. Percent of vegetation changes for plant species growing in seedling transplant area.

will not be higher than species planted, especially on clay and rubble subsoil. To predict species success in a similar site, the species planted should be the same or, at least, have the same average conservative values.

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RESTORATION OF A BUR OAK GROVE

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Ford County, the last county to be settled in Illinois, contains a presettlement bur oak grove near the village of Sibley. The Nature Conservancy (TNC) discovered this 38-acre grove while surveying the Mackinaw River basin. The grove is located 1/2 mile east of Sibley, Illinois, (T25N-R7E-Sec 35 and 36). It was purchased by Hiram Sibley and his grandsons in 1995 and donated to TNC.

Management started in October 1995 with removal of hawthorn (*Crataegus mollis*) and reduction of black cherry (*Prunus serotina*). Inventories of the grove have started, and diameters of bur oaks (*Quercus macrocarpa*) range from 18 in. to 54 in. One bur oak, having a diameter of 39 inches, is over 325 years old. Insect surveys were scheduled for the summer of 1996, and prescribed fire has been reintroduced with small sections being burned in the fall of 1995 and spring of 1996. Surrounding groves in central Illinois are being surveyed to develop floristic lists and local seed sources for restoration efforts.

Also on site is a 12-acre agricultural field that was historically a marsh and wet prairie. Soil maps show a Houghton Muck. This soil developed on areas under water two to three months a year. A cooperative venture is underway with the U.S. Fish and Wildlife Service, USDA's Natural Resource Conservation Service (NRCS), Illinois Department of Natural Resources (IDNR), Illinois Natural History Survey (INHS), and Illinois Nature Preserves Commission. Soil bores show 20 inches of siltation on top of muck soils. A combined effort between NRCS and INHS is under way to map soils and their depths on site. Using tile maps from the 1880s, all tiles on site have been located and plans have been made for their removal. INHS has cored the muck soil and is experimenting with seed bank studies.

Over 60 volunteers are involved with efforts and they strongly endorse TNC's ownership of the land and restoration efforts.

HABITAT CHANGES AND TRENDS AFFECTING SELECTED POPULATIONS OF SISTRURUS CATENATUS CATENATUS (EASTERN MASSASAUGA) IN MICHIGAN

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ABSTRACT: In Michigan, the eastern massasauga (*Sistrurus catenatus catenatus*) occurs across the Lower Peninsula in prairie fens and other minerotrophic wetlands. This species has declined in most other parts of its range and has been under consideration by the U.S. Fish and Wildlife Service for federal listing as endangered or threatened. Motivated by similar concerns, a statewide status survey was conducted in Michigan between 1993 and 1995. Methods included field surveys, landowner interviews, and solicitation of sightings from professional field biologists. A total of 143 recent population locations were found, with concentrations in several of the state's ecoregions. Five populations representing different ecoregions were selected for analysis of historic habitat changes and trends. The selected populations varied in ownership type, degree of protection, natural community type, apparent population numbers, and habitat quality and quantity. For each location, data were gathered on habitat loss and change from presettlement to recent conditions, local human population and land use trends, and local massasauga occurrence. These data were used to summarize the habitat changes and threats to eastern massasauga populations under similar conditions throughout Michigan. In areas that have already been heavily developed, massasaugas tend to become isolated on patches of public land. There they are threatened by habitat change, human persecution, and isolation. In other locations, development is in an intermediate stage or is proceeding more slowly, presenting opportunities for the conservation of larger, less isolated populations. Strategies for massasauga conservation will necessarily vary in different parts of the state.

Key words: eastern massasauga, Lower Peninsula, wet prairie, wetland, coniferous swamp

INTRODUCTION

The eastern massasauga (*Sistrurus catenatus catenatus*) is an uncommon reptile species occurring in localized populations in parts of the Great Lakes basin and northern Mississippi River valley. Biologists have been concerned about a perceived decline in this species in recent years, and the U.S. Fish and Wildlife Service (USFWS) has been considering it for federal listing as a threatened or endangered species. As a result, status surveys have recently been conducted in most U.S. states in their range and in Ontario, Canada. These surveys have uniformly pointed to a severe decline in the number of extant populations (Davis and Menze 1996, Weller and Oldham 1993, Reinert and Bushar 1993, Beltz 1992, Hay and Kopitzke 1993, Christiansen 1993, Nordquist 1994). Michigan has been thought to be a stronghold for the species, where it occurs across the Lower Peninsula, but concerns over its statewide status have been increasing. The species was first listed as "Special Concern" in Michigan in 1991. At that time *Sistrurus c. catenatus* populations were known from 90 discrete locations statewide, but only 3 of these have had sighting data since 1989.

Relatively few ecological studies have been done on Sis*trurus c. catenatus*, widely considered to be a shy, secretive species. Current information indicates differential habitat use across its range, though always including a wetland component. Typically these wetlands are open, including wet prairie and associated marshes in Missouri, Iowa, and central Wisconsin (Siegel 1986, Christiansen and Bailey 1990); wet prairie/woodland borders in Illinois (Wright 1941, Mierzwa 1992); and wet, open meadows in Pennsylvania (Reinert and Kodrich 1982). In northern portions of its range, *Sistrurus c. catenatus* associates more with forested wetlands such as river bottom forests in Minnesota and central Wisconsin (Vogt 1981) and lowland conifer forest in Ontario (Weatherhead and Prior 1992). Both forested and open wetland communities are used in Michigan (Holman et al. 1989). Southern populations typically are associated with prairie fen, a type of open wetland, while those in the northern Lower Peninsula are better known from lowland coniferous forest.

Eastern massasaugas have demonstrated seasonal habitat shifts in some areas, showing a preference for dry, open uplands during the summer and various types of open wetlands the remainder of the year in studies in Pennsylvania and Missouri (Reinert and Kodrich 1982, Siegel 1986). In Michigan, farmers often report finding massasaugas in upland pastures and hayfields during the summer. Snakes in the Bruce Peninsula of Ontario did not demonstrate such a clear seasonal habitat differentiation, but had much larger home ranges (Weatherhead and Prior 1992). Ontario massasaugas showed an average home range of 25 ha compared to 1 ha for those in Pennsylvania.

A Michigan status survey for the eastern massasauga was first begun in 1993 (Legge and Rabe 1994). The current study expanded upon that pilot effort and sought to document the locations of all recently extant Sistru*rus c. catenatus* populations in Michigan, summarizing their areas of concentration in the state. (Other aspects of this study are described in Legge 1996). In addition, five representative populations were selected and analyzed for historical habitat changes. The goal of this second component of the project was to provide a more detailed picture of the status and threats facing *Sistrurus c. catenatus* in Michigan.

METHODS

Status Survey

Because *Sistrurus c. catenatus* is difficult to find in the field and known historically from many Michigan locations, the 1995 inventory augmented field surveys with landowner interviews and a large mail survey, soliciting sighting information from field biologists statewide. Field surveys were conducted at 29 sites between May and September 1995. Visual surveys were done by walking through appropriate habitat and turning over rocks, logs, and other debris. When possible, both open wetland areas and bordering areas of high ground were surveyed for basking snakes. Observed massasaugas were photographed for documentation.

Residents whose homes and/or farms bordered potential eastern massasauga wetland habitat were contacted for interviews . Most of the residents interviewed had lived in the same location for ten or more years and could provide some history of eastern massasauga sightings and habitat changes in their area. Residents were questioned closely to determine their general knowledge of snakes and specific familiarity with massasaugas, allowing the interviewer to judge the validity of their sightings.

Additional information on recent eastern massasauga sightings was solicited through a statewide mail survey. Mailing packets included an introductory letter, a data sheet for 1990–1995 sightings, and a fact sheet about the eastern massasauga. Forms were sent to over 800 biologists throughout Michigan, including Michigan Department of Natural Resources (MDNR) field personnel, nature centers, college and university biological sciences departments, USFWS personnel, state registered forestry consultants, wildlife nuisance control workers, and other consultants.

To determine the number of distinct eastern massasauga populations statewide, uniform standards were applied to the location data. The species has been known to travel up to 2.4 km between hibernacula and summer range areas (Hay 1993), but no data is currently available on dispersal. Therefore, populations were judged to be distinct only if they were separated by at least 6.5 km of suitable habitat; at least 1.6 km of unsuitable habitat; or a major barrier to dispersal, such as a highway or housing development.

Locations of eastern massasauga populations were mapped in relation to the boundaries of the state's ecoregions and their subunits. As described by Albert (1995) these areas are defined by climatic, landform, soil, and vegetative components. Therefore, they were considered likely to relate to the pattern of eastern massasauga occurrence. Arranged hierarchically, the Lower Peninsula is divided between two large ecoregions (north and south), 12 districts, and 25 subdistricts (Albert et al. 1986).

Habitat Analysis of Selected Sites

Five extant populations were selected from across the eastern massasauga's Michigan range to represent the range of conditions under which the species occurs. All five populations were included in 1995 field surveys, which sought to determine whether eastern massasaugas were still present and whether an anecdotal trend in population could be identified by local landowners. The locations were selected from three ecoregion subdistricts with especially high concentrations of *Sistrurus c. catenatus* populations, including the Cheboygan subdistrict in the northeastern Lower Peninsula (two populations selected, Presque Isle South and Presque Isle North); the Battle Creek Outwash Plain subdistrict in southwestern Michigan (two populations selected, Kalamazoo South and Kalamazoo North); and the Jackson Interlobate subdistrict in the southeastern part of the state (one population selected, Oakland West) (Figure 1). The detailed information on these selected populations and changes in their habitats should illustrate the range of conditions faced by the eastern massasauga in Michigan.

In the northern Lower Peninsula, the Presque Isle South site is representative of many sites with a large area of intact habitat under partial public ownership, with more than 50 km^2 of potential contiguous habitat. The site consists of a ridge covered by second-growth northern hardwoods with scattered small openings. Agricultural lands predominate on the edge of the upland plateau at the ridge's top. A large swamp dominated by white cedar (*Thuja occidentalis*) lies on the lakeplain at the base of the ridge. The second site, Presque Isle North, is similar in terms of habitat quality, but is entirely under private ownership with increasing development pressure, a growing concern in the region. It consists of shoreline northern fen areas on Lake Huron and an inland cedar swamp and uplands, approximately 130 ha of available habitat. These two sites are only about 2.4 km apart and may have functioned originally as a single population, now divided by a busy, paved highway. The climate in this subdistrict is more severe than in the southern study areas, with twice the annual snowfall and extreme minimum temperatures ten or more degrees lower (Albert 1995).

Oakland West in southeastern Michigan is located in the eastern arm of the "Interlobate," a geologically distinctive region stretching across the southern Lower Peninsula with many *Sistrurus c. catenatus* populations. The region's name stems from its position between large glacial lobes that occupied the basins of Lake Michigan, Lake Erie, and the Saginaw Bay during the last glaciation (Dorr and Eschmann 1984). The Oakland West site contains one of the highest-quality areas of massasauga prairie fen habitat remaining in southern Michigan, with about 60 ha of interconnected, potentially usable wetland habitat along a corridor connecting two lakes. However, it is almost entirely on private land in a region with increasing residential development. A nature preserve occupies about 2 ha while the uplands include deciduous forest, low-density residential areas, and some agricultural lands. The site is on the outer edge of the Detroit suburbs and is likely to see intense development pressure in the future.

The two other southern sites are in the western part of the Interlobate on public lands hemmed in by development. The

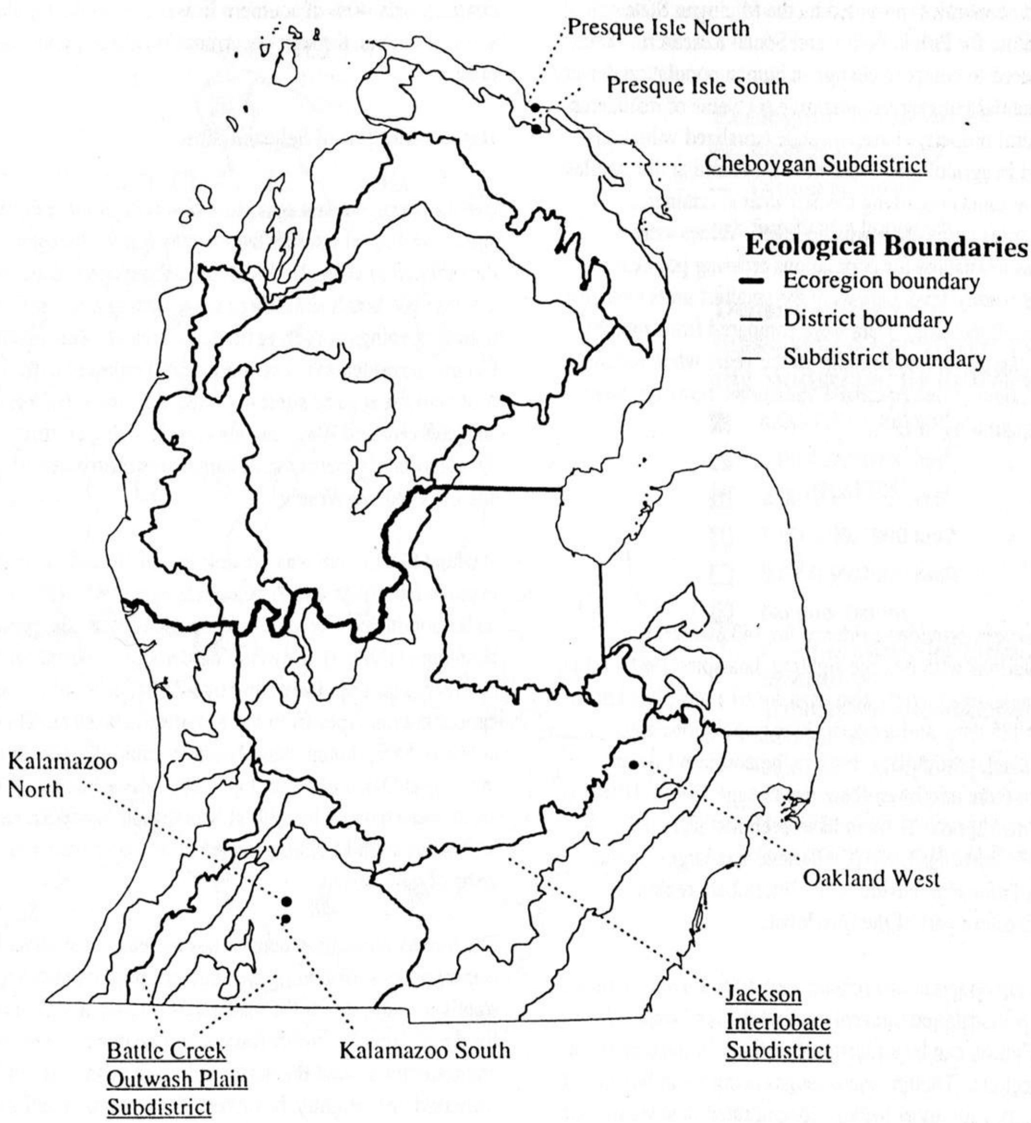

Figure 1. Eastern massasauga populations selected for habitat analysis, The ecoregion subdistricts (Albert 1995) of the sites are underlined.

Kalamazoo North population is in a municipal park that runs 1.6 km along one bank of a creek, with about 8 ha of degraded streamside wetlands. The site is ringed by residential and commercial development, and the wetland is densely covered with tall forbs and shrubs, including dense European buckthorn (*Rhamnus cathartica*). Kalamazoo South, the second study population, occurs on a state game area about 6.5 km away. The population is currently known from a prairie fen in its northeast corner with about 30 ha of wetland habitat. The fen has been mined for peat in the past and is bordered by upland forest, older residential areas, and an interstate highway.

Several databases were consulted to investigate the broader issue of landscape-level changes at the five locations. Comer et al. (1995a) has interpreted presettlement natural community composition for the entire state from the early 1800s General Land Office surveys using the notes of the original surveyors. These data were compared to 1978 landcover data from the Michigan Resource Inventory System (MIRIS) to evaluate changes in habitat availability. Calculations were made at the township level for the southern Michigan sites, approximately 93 km^2. An area twice that size was used for the northern Michigan sites. Data on total area of wetland types constituting potential eastern massasauga habitat were then calculated and compared for the sites and their surrounding areas. Changes in area of potential open upland habitats also were determined. However, eastern massasaugas are likely to only use uplands adjacent to wetland habitat, and it was not possible to limit the area calculations to that portion of the open uplands.

Other land use trends and changes in human population were examined using U.S. Census and other data on population, agriculture, and economics (provided by the Michigan State University Institute for Public Policy and Social Research). These statistics were used to compare change in human population density, growth in residential housing, comparative tax value of residential versus agricultural property (based on state equalized valuations), and area of land in agriculture. Data were measured at the smallest possible political units containing the *Sistrurus c. catenatus* populations, in most cases the township level. Values were combined across townships for populations crossing political boundaries, and county-level data were the smallest units available for area of agricultural land. Data were compared from approximately 1940 to the present, depending on the years when various measures were taken. State equalized valuations, however, were available only beginning in 1973.

RESULTS

Status Survey

The different surveys provided evidence for 143 *Sistrurus c. catenatus* populations with reliable sighting data since 1986 (Table 1). Eastern massasauga records also exist for 61 other sites known only from pre-1986 data, and some of these populations are probably still extant, particularly those in the northern Lower Peninsula where there are fewer observers (Legge 1996). However, some of these sites, appear likely to have been lost from the state. The proportion of unreconfirmed populations was largest in the southern Lower Peninsula outside of the Interlobate region, and smallest in the western part of the Interlobate.

Eastern massasauga populations remain across the Lower Peninsula, but the species is distributed unevenly across the landscape. The pattern of distribution can be understood partially in the context of the state's ecoregions. Though massasaugas occur in all but two of the subdistricts, they are most heavily concentrated in several south-central subdistricts of the Interlobate (Figure 2). Populations of *Sistrurus c. catenatus* across the northern Lower Peninsula generally occur at lower densities than those in the south. Most northern Lower Peninsula populations are closely associated with conifer swamps dominated by white cedar. Therefore, populations tend to cluster where that community occurs along the Lake Huron lakeplain and along the floodplains of major rivers, including portions of the Au Sable, Manistee, and Muskegon. Except along the northern Lake Huron shoreline, boundaries between ecoregion subunits are less useful in explaining the snake's pattern of occurrence. The subdistrict with the greatest concentration of eastern massasaugas in the northern ecoregion, a small subdistrict in the northwest, actually contains only a single population. The unit's small size gives it a high concentration of populations per unit area, however.

Although there are fewer *Sistrurus c. catenatus* populations in the northern Lower Peninsula, populations there tend to occupy larger areas of contiguous habitat that probably reflect larger populations (Legge 1996). In addition, almost three-fourths of these populations are located at least partially on public land, providing greater potential protection from development and disturbance (Table 1). In contrast, only 40% of southern Lower Peninsula populations gain some protection through occurrence on either public land or nature preserves.

Habitat Analysis of Selected Sites

Adult eastern massasaugas were observed at three of the targeted sites, and interviews with landowners confirmed their presence at the other two (Table 2). Most individuals were observed at the Presque Isle South site, where seven snakes were seen in various upland openings bordering the large area of white cedar swamp. Longtime residents (ten or more years) reported a decline in observations at three sites; the trend was uncertain but apparently stable at Oakland West, and apparently stable at Presque Isle South. Persecution of eastern massasaugas was clearly reported at every site but Oakland West.

Wetland habitat loss was greatest in and around the northern sites at Presque Isle South and Presque Isle North, where 62% of the white cedar-dominated wetlands have been lost from the presettlement landscape (Table 3). Lowland hardwoods replaced much of the lost coniferous swamp, increasing by 672 ha. Loss of prairie fen and similar habitat types from the Kalamazoo North/Kalamazoo South area was 55%, though these habitats actually registered a slight increase at Oakland West. Open uplands decreased in all of the areas, most notably by 74% at Kalamazoo North/Kalamazoo South in southwestern Michigan, an area that historically had very large areas of oak barrens.

The human population density has increased dramatically in the communities surrounding the southern populations, at four times the state's overall rate for the Oakland West area and five times that rate for the Kalamazoo North/Kalamazoo South area (Table 4). The communities around the northern Lower Peninsula populations have increased only slightly, however. The housing data follow similar trends. The proportion of all assessed property value stemming from agricultural lands has decreased at all sites. However, this is not significant for the western Interlobate populations where values indicate very low agricultural activity by 1973. At the same time, the assessed value of residential land has increased significantly. Agricultural land area has decreased in the surrounding counties of all the sites, particularly Oakland County.

DISCUSSION

Populations of *Sistrurus c. catenatus* appear to be more abundant and widely distributed across Michigan's Lower Peninsula than in most other portions of their range. Michigan populations of *Sistrurus c. catenatus* have been associated with specific habitat requirements, most notably with calcareous habitats including prairie fens and cedar swamps. This is reflected in the species' uneven pattern of occurrence in the state. There is a potential for error in the data for newly-reported populations, since many came from the mail survey without specimens or photographs for documentation. However, most reports were submitted by trained biologists, and all reports were carefully screened. Many of them were included in the data only after follow-up calls clarified sighting

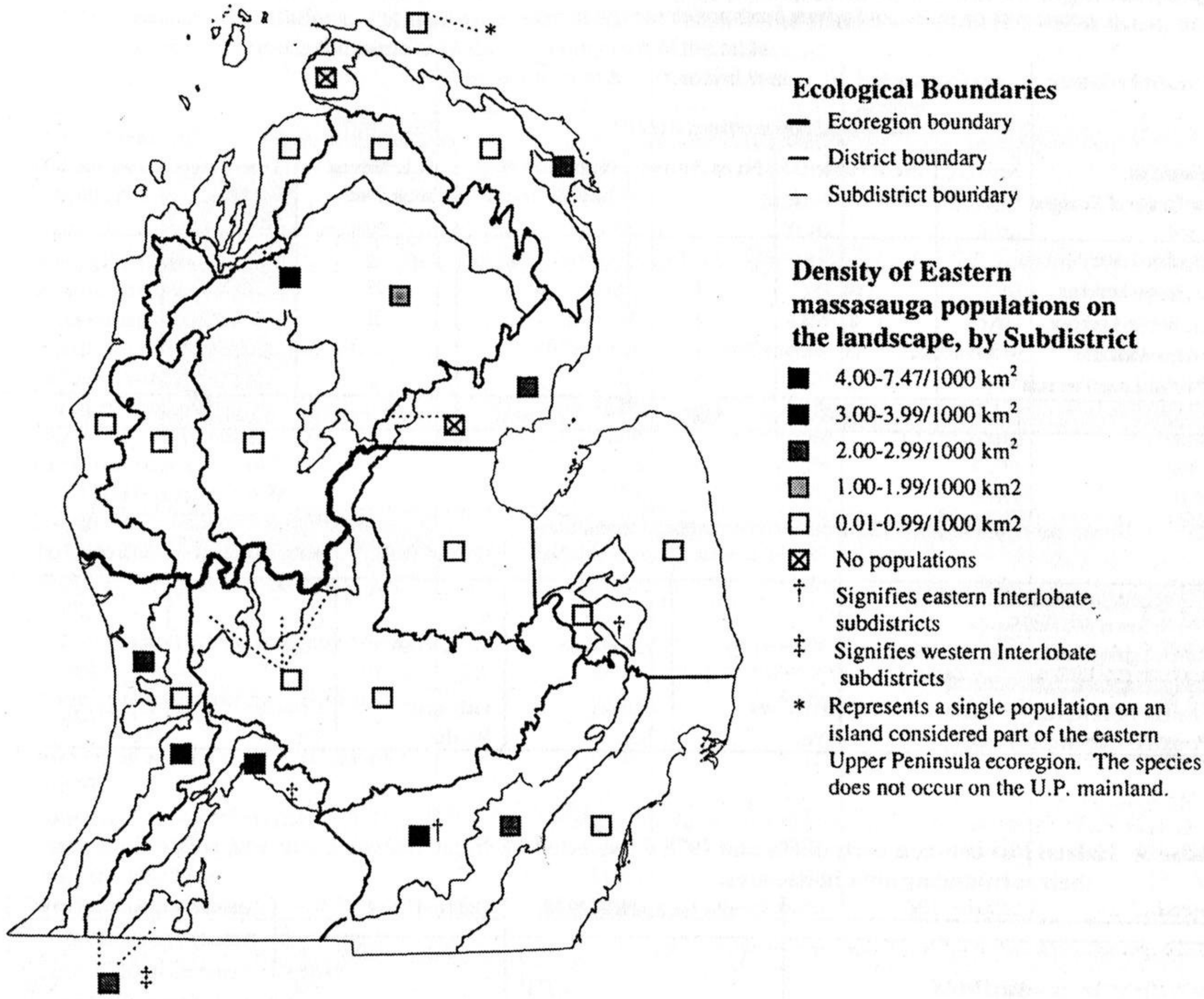

Figure 2. Density of Michigan's eastern massasauga populations with sighting data since 1986 by ecoregion subdistricts (Albert 1995). Density is measured in number of populations per 1000 km^2.

details. The resulting pattern of reliable new sightings closely mirrors the pattern for populations known from museum specimens. Therefor, the occurrence data summarized here is thought to closely reflect the actual range of this species in Michigan.

The concentration of eastern massasauga populations in parts of southern Michigan strongly reflects the boundaries of ecoregion subunits, particularly for the Interlobate region. The surface geology of the Interlobate subdistricts consists of broad, sandy outwash plains, gently sloping ground moraines, and steep-sloped end moraines, with numerous kettle lakes (Albert 1995). The presettlement vegetation was generally diverse, with uplands tending towards tallgrass prairie to the west and various types of oak savanna in the east; prairie fens were abundant along the border between the higher moraines and the outwash, where they were fed by calcareous seeps. Prior to European settlement, broad swaths of this area probably provided continuous habitat for *Sistrurus c. catenatus*, with extensive prairie fen wetlands bordering open uplands (Albert 1996, pers. comm.). Today the Interlobate's eastern massasauga populations are largely restricted to prairie fens or their degraded remnants and associated upland areas. Subdistricts bordering the Interlobate also have relatively high eastern massasauga concentrations, many of which are located in prairie fens along the edge of the Interlobate.

Prairie fens are uncommon or absent in other subdistricts of the Lower Peninsula (Albert 1995) where eastern massasaugas are also much less frequent. Although calcareous soil conditions predominate across the southern Lower Peninsula (Albert at al. 1986), surface geology and climate have produced a different pattern of natural communities than those typical of eastern massasauga habitat in the Interlobate. Prairie fens tend to be found where

Table 1: Number of *Sistrurus c. catenatus* populations occurring in various subdivisions of Michigan, and their occurrence on public and private lands and nature preserves.

Data for populations reconfirmed since 1986

Ecoregion, or Portion of Ecoregion	No. on Public Land	No. on Preserves	No. on Both Public Land & Preserves	No. Entirely on Private Land	Total No. Recently Extant	Total No. known only prior to 1986
Southern Lower Peninsula						
Eastern Interlobate	16	1	0	19	36 (25%)	17
Western Interlobate	8	4	0	21	33 (23%)	4
Non-Interlobate	13	3	0	26	42 (29%)	24
Northern Lower Peninsula	22	0	2	8	32 (22%)	16
Total	59 (41%)	8 (6%)	2 (1%)	74 (52%)	143	61

Table 2: Survey data from selected Michigan *Sistrurus c. catenatus* populations.

	Presque Isle South	Presque Isle North	Oakland West	Kalamazoo South	Kalamazoo North
1. Were eastern massasaugas still present?					
Number Seen in 1995 Field Surveys	7	1	0	0	1
Reliable Sightings from Residents, 1986-1995	Yes, as of 1995	Yes, as of 1995	Yes, as of 1994	Yes, as of 1994.	No
2. Were there notable population trends?					
Anecdotal Trends Reported by Residents	Fairly Stable	Decreasing	Fairly stable?	Decreasing	Decreasing
Persecution Reported by Residents	Yes	Yes	Possible	Yes	Yes

Table 3: Habitat loss between early 1880s and 1978 for selected Michigan *Sistrurus c. catenatus* populations and their surrounding area, in hectares.

	Presque Isle South & North	Oakland West	Kalamazoo South & North
Acres of presettlement wetland habitat	7,733[1]	928[3]	916[3]
Acres of wetland habitat, 1978	2,904[2]	1,078[4]	412[4]
Loss of potential wetland habitat	62% loss	16% gain	55% loss
Loss of potential open upland habitat[5]	18% loss	26% loss	74% loss

[1] Lands classed as lowland conifer dominated by cedar.

[2] Lands classed as lowland conifer.

[3] Lands classed as palustrine emergent marsh/meadow/prairie.

[4] Lands classed as emergent non-forested wetland or wooded/shrub/scrub wetland.

[5] For presettlement habitat, all non-forested upland, including various grasslands and savannas. For 1978 landcover, pasture lands and uplands with herbaceous or shrub-dominated groundcover.

calcareous seeps occur, generally at the base of steep topography, and the moraines, outwash plains, and kettle lakes of the Interlobate subdistricts produce ideal conditions for fens. However, the flat lakeplain of the subdistricts bordering Lakes Erie, St. Clair, and Huron do not, and wetlands there are dominated by lowland hardwoods and wet prairie (Albert 1995). Less than ten eastern massasauga sites are known from the lakeplain region. It is possible that the species was much reduced there before scientific collecting could document the extent of their occurrence. Few specimens of *Sistrurus c. catenatus* were collected in Michigan in the 19th Century, and the fertile lakeplain was developed heavily for agriculture early in the state's history, with extensive drainage of wetlands in the mid-1800s (Comer et al. 1995b). The original wet prairies of the region may have been structurally similar to currently occupied areas, termed "wet prairie" in Illinois, Wisconsin, and Missouri. If eastern massasaugas were originally more prevalent in this region, however, it seems likely that they occurred at lower densities than elsewhere in Michigan.

The subdistricts directly north of the Interlobate consist of loamy till plain and loamy end moraine and were historically largely forested; the widely dispersed massasauga populations there are associated with the few prairie fen communities along the border with the Interlobate and with a small central area that formerly consisted of wet prairie. Like the southeastern lakeplain subdistricts, this region has been heavily settled and cultivated (Albert 1995). Blocks of

Table 4: Human and land use trends in the smallest surrounding political units of selected Michigan *Sistrurus c. catenatus* populations. Political units considered are listed in the shaded area; where none is listed, the area measured is the same as in the preceding part of the table.

	Presque Isle South & North	Oakland West	Kalamazoo South & North	State of Michigan
a. Human Population Changes[1]				
Human population density, 1940	25.2/km²	11.4/km²	51.0/km²	35.6/km²
Human population density, 1990	26.6/km²	81.2/km²	492.3/km²	63.2/km²
Change in human population density, 1940-1990	106%	713%	965%	178%
b. Housing Trends[1]				
Occupied housing units, 1940	1815	573	1204	1,396,014
Occupied housing units, 1990	1909	4,865	15,467	3,195,213
Change in occupied housing units, 1940-1990	105% increase	849% increase	1,285% increase	229% increase
Total housing units, 1940	1850	854	1,438	1,519,378
Total housing units, 1990	2235	5,229	16,133	3,847,926
Change in total housing units, 1940-1990	121% increase	612% increase	1,122% increase	253% increase
Occupied:Total housing ratio, 1940	98.1%	67.1%	83.7%	91.9%
Occupied:Total housing ratio, 1990	85.4%	93.1%	95.9%	83.0%
c. Comparative Tax Value of Property, from State Equalized Valuations[2]				
Percentage of real assessed total classed as agricultural, 1973	21.1%	31.6%	0.9%	7.6%
Percentage of real assessed total classed as agricultural, 1993	14.2%	6.7%	0.1%	4.5%
Percentage of real assessed total classed as residential, 1973	47.4%	68.3%	66.1%	60.3%
Percentage of real assessed total classed as residential, 1993	64.6%	85.1%	66.3%	70.2%
d. Agricultural Land Area (by county)[3]				
Land in farms, 1945 (hectares)	67,179	144,474	111,290	7,443,058
Land in farms, 1987 (hectares)	33,055	27,945	68,113	4,175,130
Change in acres of land in farms, 1945-1987	50.8% decrease	80.7% decrease	38.8% decrease	43.9% decrease

[1] Source: U.S. Census Bureau
[2] Source: Michigan Department of Treasury
[3] Source: U.S. Census of Agriculture
All data provided by the Michigan State University Instuture for Public Policy and Social Research.

uplands there are larger than in the Interlobate and there are few kettle lakes, so that calcareous seeps tend to occur mainly where uplands meet ravines or floodplains along rivers and streams (Albert 1996, pers. comm.). It is possible, therefore, that prior to settlement more eastern massasauga populations existed in fen wetlands of river corridors that have since been destroyed.

Similar conditions prevail in much of the northern Lower Peninsula, where most occurrences are clustered in calcareous, white cedar-dominated swamps along portions of various rivers. These rivers tend to cross ecoregional boundaries, which are thus less meaningful for explaining occurrence patterns than in southern Michigan. However, *Sistrurus c. catenatus* populations do concentrate in the Cheboygan subdistrict. The Presque Isle South site there is typical, with lakeplain white cedar swamp at the base of higher uplands that parallel the shoreline. Eastern massasaugas also have been recorded in other natural communities in the northern Lower Peninsula, including northern fen, dry-mesic prairie, and jack pine barrens, but almost always in areas close to coniferous swamps. The species generally is not reported from large expanses of upland hardwood forest or jack pine barrens.

This lower density of eastern massasauga occurrences in the north is probably artificially elevated by several factors, including the sparser human population, with correspondingly fewer observers on the landscape. Doubtless, some undocumented eastern massasauga populations remain in this region. It also is likely that habitat fragmentation has increased the number of discrete populations represented in the south, a trend much less prevalent in the northern Lower Peninsula. Because of the association with river systems, it would be valuable for future surveys to target areas along northern Michigan rivers with occurrences of cedar swamp. Systems flowing north and emptying into Lake Huron in the Cheboygan subdistrict may be especially likely to contain unidentified *Sistrurus c. catenatus* populations (Albert 1996, pers. comm.).

Among the sites examined in detail, the worst-case scenario for the eastern massasauga occurs at the two locations in the western

Interlobate, Kalamazoo North and Kalamazoo South. Both of these sites have become isolated by development and major roads, and declining populations are apparent to local residents. This was particularly noteworthy at Kalamazoo North, where older, bordering landowners recalled that massasaugas appeared commonly on their land when celery fields occupied the neighboring lots, up to "20 to 30 years ago." The area is now solidly residential, and they recalled last seeing (and killing) a massasauga about ten years ago. No other recent massasauga sightings were reported there, and the species probably no longer occurs outside the park. At Kalamazoo South, a local herpetological enthusiast has visited the site frequently since 1979, relocating more than fifty eastern massasaugas to the site as part of a wildlife control business. Nevertheless, he has not seen any individuals at the site since 1986, though neighbors of the game area report seeing (and killing) massasaugas as recently as 1994.

The community surrounding these sites has grown dramatically since 1940, increasing almost ten-fold, while wetland habitat has declined dramatically by 55%. Thus, public lands supply the only remaining refuges for *Sistrurus c. catenatus.* in this region. This development pattern occurred relatively early, so that by 1973 only 0.9% of the assessed property value in the community stemmed from agricultural land, and the relative value of residential land has remained steady over the ensuing 20 years. The absence of nearby agricultural land for upland foraging areas may be a significant problem for these populations; forays into bordering, open uplands are likely to lead them into residential yards or grassy, recreational parkland where they may be killed by humans. Without efforts to educate residents and park visitors, such populations are probably doomed. Currently there are 29 other populations across the southern Michigan Interlobate that are similarly known from parks, public lands, or nature preserves, and 14 of these (mostly in the eastern Interlobate) appear similarly isolated by development.

The conditions for the eastern massasauga at Oakland West are among the best remaining in the eastern Interlobate portion of southern Michigan, with a large core of prairie fen and other wetland habitat. Although the land cover data indicate a 16% increase in eastern massasauga wetland habitat here, this does not represent an expansion in wetlands overall. The increase stems mainly from the change of presettlement wetlands classed as lowland tamarack forest to shrub-dominated wetlands, since only the latter type was considered potential habitat. The prairie fen core has remained since presettlement despite a seven-fold increase in human population density since 1940. However, the pace of development may be slowing somewhat, as seen in the increasing ratio of occupied housing to total housing available, up to 93.1% in 1990. The significance of increased development is reflected in the proportion of total assessed value of land in the surrounding townships. The proportion stemming from agricultural land in the area dropped by 24.9 % over the 20 years ending in 1993, while the value of residential land increased to 85.1% of the total. This mirrors the 80.7% decrease in area of agricultural land in the county. These losses of agricultural lands result in a decrease of potential open upland habitat for *Sistrurus c. catenatus.*

Sites like Oakland West are uncommon in southern Michigan, and development patterns for other parts of the eastern Interlobate foreshadow the likelihood of intensive development of the area. Like the populations at Kalamazoo South and Kalamazoo North, this site is probably fated to become surrounded by development. However, there is still an opportunity to preserve a much larger core area of habitat at this site, giving the massasauga population better long-term viability. Conservation of the site has recently been initiated cooperatively by local governments, a local land conservancy, and The Nature Conservancy. Conservation action in this case has been motivated by the high quality of the prairie fen there and the presence of several rare insects and plants. Such action is unlikely at many other privately owned sites occupied by *Sistrurus c. catenatus* in the Interlobate that are of lower overall quality, and many of these sites will probably be lost to development over time. There are 40 eastern massasauga sites located entirely on private land across the Interlobate region. Sites with high-quality habitat comparable to Oakland West are more likely to be found in the less intensively developed parts of the Interlobate, including central (Jackson County), northwestern (Barry County), and southwestern (Cass and St. Joseph counties) areas.

The eastern massasauga populations at Presque Isle North and Presque Isle South are representative of the circumstances of many sites in northern Michigan, which have the best long-term prospects for conservation. The Presque Isle South site is particularly hopeful, with a comparatively vast area of intact habitat and relatively little human intrusion. Although wetland habitat here has decreased drastically (62%), the remaining area is still relatively large, at more than 2900 ha. This habitat is also largely contiguous. Interestingly, some of this loss has been the result of the conversion of white cedar-dominated wetlands to lowland hardwoods, a community not known to provide favorable eastern massasauga habitat in Michigan.

Human population has been much more stable in the local area, and housing has also increased at a comparatively moderate pace. However, development pressure is present in scenic areas like the shoreline at Presque Isle North and along a river flowing through part of the swamp at Presque Isle South. Much of this growth is in vacation homes and cottages, which is not reflected by human population statistics. Despite some human persecution at both sites, development appears likely to be limited to the margins of massasauga habitat here. Agricultural lands providing upland foraging habitat are probably less likely to be developed. Although agricultural land has declined by half in the county overall since the 1940s, this is not significantly different from the change in cultivated lands in the state overall. The comparative value of agricultural land in surrounding communities declined by a third from 1973 to 1993, but still remained three times the value for the state overall. The development potential of this area demonstrates that even in this part of Michigan, conservation of *Sistrurus c. catenatus* populations cannot be taken for granted. Public education regarding the species' rarity and low potential threat has been done in similar areas in the Bruce Peninsula of Ontario (Johnson 1993) and could also be critical for conserving northern Michigan populations with significant private ownership. There are 12 other large eastern massasauga sites across northern Michigan similar in size to the Presque Isle South site, most of which contain a mixture of public and private land.

Increasingly intensive human land use can be expected to continue across the Lower Peninsula. With continuing trends in low density housing patterns and smaller household size, the amount of residential land in Michigan is expected to increase dramatically between 1990 and 2020, by 566,000 to 800,000 ha. This will double the amount of residentially classed land from the 1978 MIRIS land cover survey (Smyth 1995). The intensity of this change will differ locally, but many areas with significant numbers of eastern massasaugas are expected to grow at rates higher than the 11.8 percent human population increase for the state overall. Many counties in the Interlobate and most northern Lower Peninsula counties are projected to increase at two to eight times that rate (Smyth 1995).

The differences in current conditions and future trends result in different conservation possibilities for *Sistrurus c. catenatus* across Michigan. In heavily developed areas of southern Michigan, many populations remain only on islands of public land or other small, natural remnants. Some areas with larger, high-quality habitats remain, but many of them are likely to be inundated by development. In the northern Lower Peninsula, larger contiguous areas of habitat provide more opportunities for the species' preservation, particularly where they occur on public lands. Development pressure is still a concern in this region, but mostly in more scenic areas. Intensive human use is likely to increase in all landscapes, and education efforts may be a key across the state for assuring the co-existence of eastern massasaugas with humans. Sistrurus c. ca*tenatus* may otherwise become limited to well-buffered public lands, at least in southern Michigan.

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NORTHCENTER NEIGHBORS RIVERBANK RESTORATION PROJECT

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ABSTRACT: As water quality improved, a Chicago neighborhood sought out a new relationship to the river that ran through it. Partnership with the land-owning agency and a river advocacy group helped the neighbors come to consensus and begin the work of restoring native plants and community access to the river.

Key words: Northcenter neighborhood, Friends of the Chicago River, Riverbank Restoration Project

INTRODUCTION

The Chicago River was once a relaxed, meandering stream draining a small watershed bordered by the glacial moraine to the west and Lake Michigan Dunes on the east. The area we are concerned with was a marshy, lowland transitional area, where the immense black earth, tallgrass prairie met the sandy lake plain. Old maps (Figure 1) show the river's original meander through what are now the alleyways and streets of the Northcenter neighborhood, and the site of Waters Elementary School.

The river was straightened and deepened early in this century, and for the past 80 years has served the city as a drainage ditch, flushing its sewage and treatment plant effluent with lake water down the Illinois-Mississippi River system. For most of this century the river was toxic and smelly and avoided by citizens and planners. In this neighborhood the river and bank were left to rats and adventurous children and used as a garbage dump and drinking place.

In the past two decades the river has convalesced. Although the bottom sediments remain a witch's brew of toxic chemicals and heavy metals (Leki 1994a, NIPC 1993), the Deep Tunnel combined sewer overflow control project has dramatically reduced the dumping of the combined mix of raw sewage and rainfall runoff (and subsequent oxygen depletion) into the river. The sewage treatment plant upstream at Howard Street ceased chlorination of its effluent. Over the past decade life has returned to the river. More than two dozen fish species have been surveyed (Leki 1994b). Crayfish, herons, kingfishers, raccoons, and opossums coexist with humans.

This reborn river system is reasserting itself in the middle of one of the world's great industrial megalopolises. A block away the air is thick with traffic fumes, the eyes dazzled by the glare of used car lots, and the ears assaulted with the screech of elevated train wheels. By our river, the land drops away and children hunt frogs, lovers watch herons feeding, and elders ponder questions big and small —under black willows at the edge of the water.

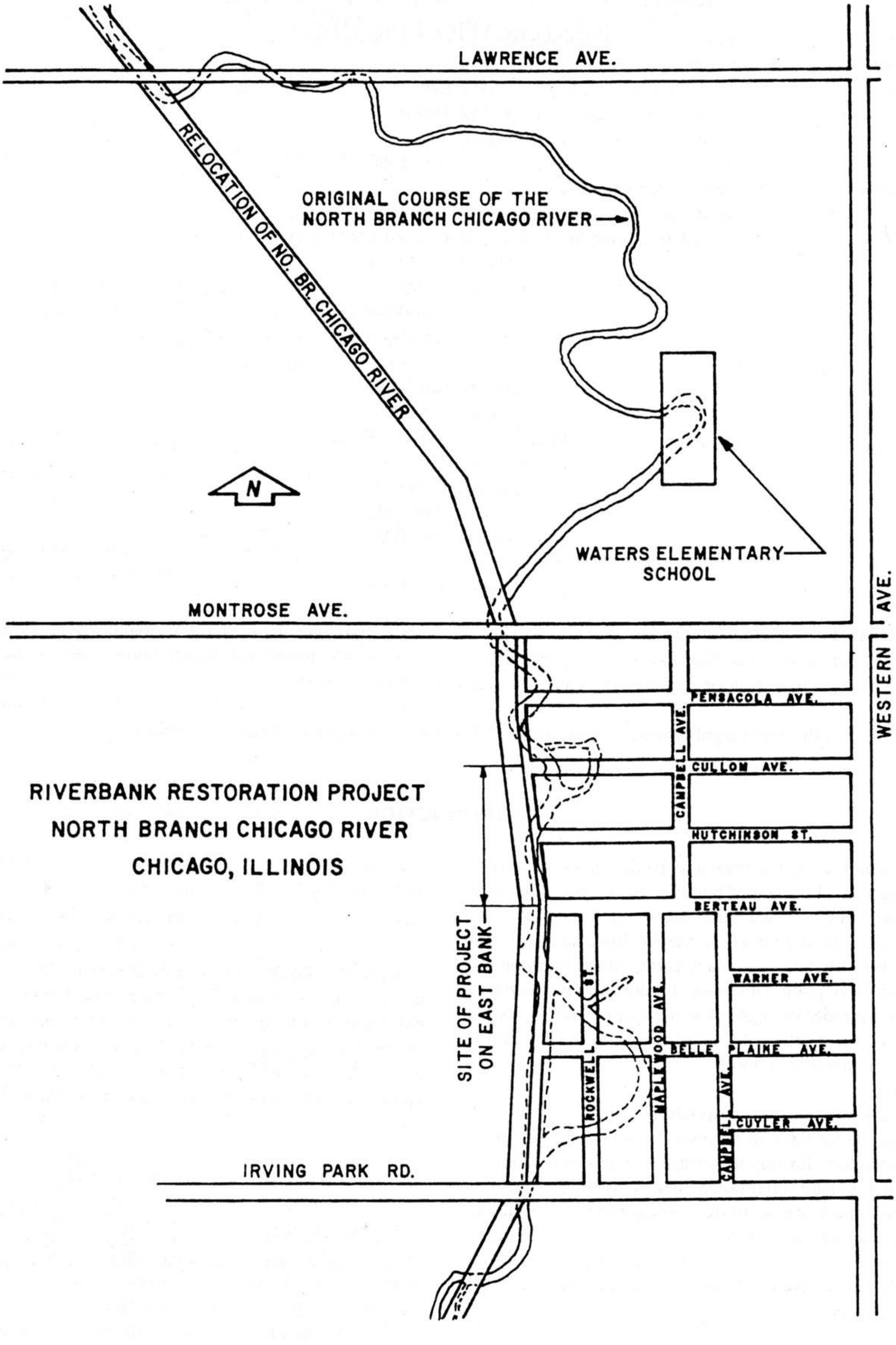

Figure 1. Map showing location of Riverbank Restoration Project.

DISCUSSION

The river in the Northcenter neighborhood is unique. It is one of the only sections along the North Branch that lacks a fence to block public access. For three city blocks (from Berteau to Montrose) the river is accessible. Many people in the neighborhood had watched the river improve over the past decade. Although the bank was a tangle of over-grown shrubs, vines, and trees, and was strewn with garbage and construction refuse, it was an inviting refuge for wildlife, migratory birds, and bird watchers. It also attracted kids with firecrackers and adults with whiskey and beer (Leki 1993). Some neighbors wished that a fence would be built to discourage these annoying visits (Leki 1994c).

Others saw the riverbank as an opportunity to create a public place for walking, talking with neighbors, or just enjoying a quiet moment (Leki 1994d). Still others saw in the sloped banks as an opportunity to improve wildlife habitat—to attract the birds and butterflies that once swarmed here, and that were now barely hanging on in tiny populations. Some neighbors had been involved in efforts to restore native ecosystems in the nearby forest preserve (Leki 1994e).

Prior to the fall of 1994, different neighbors took the initiative to realize their own riverbank visions. Kids and raccoons scoured paths through the brush and rubble, one neighbor cleared a section of bank of vegetation and planted something recommended by the local garden center, someone built a bench, someone else had the bench removed, and someone fenced off their own private section of riverbank. These jerky fits and starts to establishing a new relationship between the river and the people often caused small conflicts and resentments (Riverbank Neighbors 1995).

Locals were conflicted over a number of issues. Some were concerned that benches and steps would invite gangs and drunks. Some thought that the riverbank should be left alone in a "natural" state—whatever that might look like. One asserted that the riverbank near his home was his, and he didn't want any trespassing.

Lacking any organized process for reconciling the different views and lacking permission from the land owner, the Metropolitan Water Reclamation District (District), individuals tended to do what they could get away with. However, as a small consensus formed for restoring native grasses and forbs to the site, a number of local residents began to look about for help.

That group contacted the Friends of the Chicago River (Friends). At that time, Friends was looking for a few "demonstration" projects that it could undertake as part of a new collaboration with the National Park Service (NPS) . Through this collaboration, Friends, the NPS, and numerous other federal agencies were seeking to better understand and find ways to implement river restoration projects in an urban setting.

Friends decided to take an active role in this particular project because it possessed certain critical success factors. Because every stretch of the Chicago River system is a potential project, Friends has adopted an operating philosophy to implement those projects that have the greatest chance of success. The Friends describes this as their "go for the light" approach.

The Friends helped the neighborhood to organize a public planning process for the restoration of native plants to the site and introduced locals to representatives of the property owner, the District.

The role of the District in this project evolved from its ownership of the riverbank and from its interest in developing beneficial uses of the river. Each of these reasons for project involvement brought interesting and sometimes conflicting issues for the District.

The District is a single-purpose unit of local government formed under the Illinois statutes with authority to collect and treat wastewater from residential, commercial, and industrial sources. The river system into which the effluent from the District's water reclamation plants (WRPs) discharge have been improved to increase the discharge capacity of these rivers to convey the treated effluents and to provide adequate stormwater management. Incidental to improvement for these purposes has been the capability to allow commercial and recreational navigation. Most of the discharge in the river system consists of the treated effluent from the WRPs. During periods of excessive rainfall, river system discharges include overflows of combined sewer outfalls and stormwater runoff.

Over the years, the District has improved and expanded the capacity of its WRPs to achieve a high degree of treatment of wastewater, including capture and treatment of combined sewer overflows. For nearly three decades, there has been a positive trend in the water quality of the rivers. This improvement in water quality has attracted development along the rivers, as well as increased usage of the rivers for recreational purposes. The District has actively publicized its efforts toward improved water quality to demonstrate its dedication and responsibility to achieving environmental goals.

Thus, its efforts to assist the community in the Riverbank Planting Project was an extension of its dedication to improving the beneficial uses of the river, as well as a demonstration of its support for development of the river as an urban amenity.

In the fall of 1994 neighbors, with the help of Friends and the District, formulated the Riverbank Restoration Project.

It included the following objectives:

- to clear the riverbank of rubbish and unwanted shrubs, trees, and vines in order to gain visual access to the river from the top of the bank and to discourage undesirable activities in hidden places;

- to create well-marked paths and stepways to make the river safely accessible to visitors, young and old;

- to mitigate erosion through the building of terraces on the sloped bank using existing materials (branches, tree trunks, chunks of dumped concrete) and to re-introduce to the site a matrix of native forbs and grasses that would, over time, develop a tough turf, bloom throughout the year, and maintain a low bank profile. These re-introduced plants would create an improved habitat for native birds and insects, adding to efforts to recover these unique local populations (Leki 1994f).

The Friends helped the locals acquire funding for the purchase of plants, tools, top soil, community celebrations, outreach, buses, and supplies to bring into the project a sixth grade class from Waters Elementary School.

More importantly, the Friends and District helped the project develop a timeline and management plan for the site that was scrutinized by the Trust and experts from The Nature Conservancy and Chicago Botanic Gardens. The Friends helped present the plan at public meetings to which all neighbors were invited. This critical step helped to generate interest and support, diffuse opposition, calm fears, and formulate the management plan based on community input.

Work began in the spring of 1995 and was performed by neighborhood volunteers during Saturday workdays. Each section of bank was tended to by an adjacent neighbor who kept close daily watch over it. Larry Hodak, who lives across the river and is a founder of the North Branch Prairie Project, provided valuable technical expertise, experience, and an endless flow of native woodland flowers from his tiny backyard. Other plant plugs were purchased from the Natural Gardens in St. Charles, Illinois.

The actual planting of indigenous forbs was performed as part of a classroom unit by sixth graders at Waters Elementary School. The funds raised for the project covered purchases of plant stocks, field guides, and the cost of field trips. The children studied the Chicago River system and the flood plain slope at the local forest preserve, they selected appropriate native plants, learned to use and devise taxonomic keys, planted a nursery garden at the school grounds for seed stock, and toured the river on a pollution control boat belonging to the District.

Waters Elementary School, undergoing a vigorous effort to reform its teaching and learning, jumped at the opportunity to take part in an experiential, socially valuable learning project (Leki 1994g). The educational component invested student energy and enthusiasm into the project and created a youth constituency that all hoped would help assure the project's success and protection in the future.

Neighborhood workdays became a time for meeting new friends and deepening relationships. This was work that everyone knew was good for the community, and it was a lot of fun. The terraces and branch-wattle fencing, the wood-chipped paths, and step-downs were very beautifully done by people learning and experimenting on the job. Neighbors brought trays and baskets of refreshments, adding to the sense of togetherness (Leki et al. 1996). Those who worried about misbehaving kids could see dozens of children working diligently along side adults. For Hutchinson Street residents, these workdays spawned their first ever block party, which in turn included tours of the riverbank.

The city of Chicago provided wood chips and hauled away garbage and sections of traffic barricades that had blocked the river view.

The River was viewed by many as a nuisance before our project began. Today advocates and skeptics alike see the river as a prized neighbor. Local realtors who list properties in the neighborhood note their nearness to the "riverside nature trail." Neighbors and visitors meet at the river to relax and socialize, to play or meditate. The banks bloom with native wild asters and woodland sunflowers. Plans are underway to enrich the species mix in areas planted during the first two years and to extend the project into new areas. The neighborhood—ethnically mixed, working class, and densely urban—has become more highly valued not only because of the newly restored river bank but for the growth of the community that did the restoration.

The Riverbank Restoration Project received an Award for Outstanding Educational Work from American Rivers, a Washington-based, national lobbying group for clean water and healthy watersheds. Despite the good press, the success of the project, and the input of Waters Elementary School's students and neighbors working on the site, the project has never been officially permitted by the District, although it has been endorsed and supported in other ways.

The District, as owner of the property on which the Riverbank Planting Project was performed, was aware of potential liability to project participants if they were injured or harmed in performing the required improvement work on District property. Therefore, the District did not wish to formally acknowledge its role in approving the use of this property for the purposes of the Riverbank Planting Project. This concern for liability made the District a "silent" partner in this project. The District has contributed resources in the form of labor and equipment for work on-site. It also contributes professional time in assisting in the preparation of project plans.

The District recognizes that the public has access to, and utilizes, this public right-of-way because it makes no effort to limit public access to these properties. Despite existing statutory limitations on the liability of public agencies whose ownership of land is dedicated to conservational and/or recreational uses, the District is not willing to openly identify itself as a conservation-oriented agency, even though its mission and purpose is to protect and preserve the water quality of Lake Michigan and metropolitan Chicago area rivers.

The project may have helped create a stronger constituency for public access and restoration of public spaces. The Northcenter neighborhood and its riverbank already had certain essential features that made it the lucky recipient of Friends and District staff time.

CONCLUSIONS

The unique "Go for the Light" factors that have made this project possible are:

1. **Expressed Community Need** – Some months before the current project took form, Friends had been asked by local residents to help address a severe bank slumping problem here—a huge chunk of riverbank about 30 feet long had slumped into the river. In time, this project evolved into community-driven work on a stretch of river about three blocks long.

2. **Local Leadership** – Local neighbors like Pete Leki, Bill McBride, Simon Reeves, and Jerry Jaeckes expressed interest in restoring and improving the riverbank on their own. With the advice of local professionals and ecologists, they began physical work on the river's edge. They brought their vision to the project, organized workdays for neighbors, and held community meetings. They turned the project into a neighborhood beautification, safety, education, and ecological restoration project.

3. **Larger Policy and Program Objectives** – While all of this work was going on, Friends was working on an important policy issue on a three-mile stretch of river containing this project site. Some local residents had begun building private docks, fences, and other structures on the public river edge, closing out use by other neighbors and prompting legislation that would allow the river edge to be sold to those people who had built the structures. The goal was to eliminate the landowning agency's exposure to the liability nuisance caused by the structures (Leki 1994h). Friends opposed the legislation and the sale of the public river edge to private parties, and saw the Northcenter Neighbors Riverbank Project as a means of demonstrating that local people enjoyed and cared for the river, and that they could help the land-holding agency with management of the river. Moreover, it demonstrated that the land had value to the public for community use.

In addition, this project presented an opportunity to define restoration alternatives for our river. Across the country people are restoring rivers and streams. However, on our channeled, ditched river we cannot use those same techniques. This project, with planting terraces for native plants and safety and beautification measures, represented an opportunity to define what restoration means in our quirky, degraded river landscape. This restoration project, therefore, supported the broader goals of the Friends and the District.

4. **Funding** – Friends was able match up this local initiative with available funds.

Money, local leadership, volunteers, community interest, and a big picture reason for undertaking the project are the keys to success. Behind all of these is personal motivation to improve our communities and the environment, no matter how degraded the ecosystem. Where people are united to do good, good things happen.

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SEASONAL FIRE EFFECTS ON SPECIES RICHNESS IN A MIXED-GRASS PRAIRIE OF CENTRAL TEXAS

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ABSTRACT: Prescribed burning increases forb species more than grass species, and, therefore, overall species richness. Cool- and warm-season plants are more evenly represented in an area burned in spring and summer than one burned only in spring, and unique species occur in the areas burned in different seasons.

Key words: tallgrass prairie; mixed grass prairie; fire; species richness; species diversity

INTRODUCTION

Burn season is a much-debated topic among conservation and restoration biologists (Hulbert 1984, Howe 1994a). While fire season affects species richness in the tallgrass prairie (Collins and Gibson 1990, Howe 1994a), the question remains whether other prairie systems will experience an increase in species richness due to a seasonal fire regime. An alternating regime of dormant season and growing season fire should predispose a prairie to have a much greater species richness.

This study examined the difference in species richness in an area of mixed grass prairie that had been burned during the spring (1993) and again in late summer (1994) with an area burned in one season only (spring 1993) and an unburned area.

Study Site

Mother Neff State Park (MNSP) is the oldest state park in the Texas parks system. The park is located in Coryell County, approximately 110 km northwest of Austin in the Grand Prairie region of Texas (McCaleb 1985) and is situated at the southern reaches of the Comanche Plateau along the Balcones Escarpment (Hill 1902). The area is classified as part of the Juniper-Oak Savanna (Kuchler 1964). Mother Neff State Park occupies 105 ha, with the park topography and vegetation varying from flat flood-plain with large pecan and oak trees to rocky hills heavily wooded with both hardwood species and juniper to an area of mixed-grass prairie. The prairie is located on 32 ha of what was once rangeland in the northernmost portion of the park and can be classified as mixed grass prairie with some tallgrass prairie characteristics. The area within the prairie slopes southward at 1–6% toward the Leon River basin and has an elevation range of 216 – 35 m. Soil and underlying rock within this area are identified primarily as clay and limestone. The soil types vary from Bolar gravelly clay loam (1–4% slopes) in the lower elevations, through Eckrant cobbly silty clay (1–3% slopes), to Purves gravelly, silty clay (1–5% slopes) in the northernmost corners (McCaleb 1985).

There are no major natural water features within the prairie. A man-made pond is present near the northeast boundary and water levels vary depending on rainfall. No large depressions or sinks are present and the water table is generally greater than 1.8 m (McCaleb 1985).

There is no record of agricultural activities on the prairie other than cattle grazing. Grazing was halted in 1978, from which time the prairie remained undisturbed until 1993. During that time, Ashe juniper (Juniperus ashei) spread dramatically from the fencelines of the area into the interior (McCall 1995, unpubl.). In 1993, the Texas Parks and Wildlife Department (TPW) began the current burn regime aimed at juniper control and prairie restoration. Research has shown that several species of juniper, particularly eastern red cedar (Juniperus virginiana), can be invasive in the absence of fire (Hulbert 1984) or other disturbances. In a study conducted to determine the extent of juniper encroachment on the prairie at MNSP, an aerial image taken in 1972 showing 25–50 juniper trees within the interior of the prairie was compared to an aerial image taken in 1991 with more than 600 trees visible (McCall 1995, unpubl.). This area was essentially undisturbed from 1978 until 1993 when TPW began a burn regime in an attempt to remove and prevent further encroachment of the cedar.

METHODS

In 1994, Baylor University was contracted by TPW to assess the effects of two prescribed burns. The purpose of the burns was to reestablish what TPW perceived to be a native prairie and to remove and prevent further encroachment of Ashe cedar. This study examined the difference in species richness in three areas of the prairie: 1) unburned, 2) burned once in the spring, and 3) burned in both spring and late summer. No baseline data were available for comparison, therefore statistical analyses were limited. This study will provide baseline data for future prairie management regimes.

Two prescribed burns were conducted on the prairie at MNSP with different portions of the prairie burned in different seasons. Except for a small tract of land at the southern end, the prairie was first burned in March 1993. A portion of this burned area was again burned in August 1994.

The null hypothesis of this study was that differences in species richness within the three treatment areas were not due to treatment (burning). For the present analysis, the treatment areas were divided into: 1) the area burned only once (March 1993), 2) the area burned twice (March 1993 and August 1994), and 3) the area not burned. Sample plots were established in each of the treatment areas within the Bolar gravelly clay and Eckrant cobbly, silty clay soils. Both soil types are similar in composition, slope, and depth to limestone (McCaleb 1985). Establishment of transects and data gathering followed the Western Region Fire Monitoring Handbook published by the National Park Service (NPS 1992), which is used by TPW. Thirty points were randomly located, 10 in each treatment area to be sampled in equal seasons. A drought during the summer and fall of 1995, brush burning on the prairie by TPW in 1995, and a failed burn in February 1996 reduced the number of points that could be sampled to 19 (5 in the area unburned, 9 in the area burned once, and 5 in the area burned twice).

A two-way analysis of variance (ANOVA) was used to test the dependent variables (total species richness, grass richness, forb richness) according to treatments (2 burn, 1 burn, 0 burn) and sampling season (spring = cool season, summer-fall = warm season). Also examined was the comparative influence of grass and forb richness on total richness, using a multiple stepwise regression (Appendix C). $P < 0.05$ was the alpha level of significance (Ott 1993). The species composition of each treatment area was examined for percent composition of both warm- and cool-season plants so that a comparison could be made between species composition in areas burned in different seasons. The ten species most often intercepted were compared among treatments to determine if the season of burn affected the occurrence of different dominant species. Neither species composition nor dominant species were analyzed statistically because of the lack of preburn information.

RESULTS

Seventy-two species representing 26 plant families were intercepted along the transects established in the 19 plots. Fifteen grass species and 57 forbs and woody plants were intercepted. Ninety-four percent of these species were native to Texas (Hatch et al. 1990).

The two-way ANOVA analyses indicated that the differences in total species richness and grass richness due to treatments or seasons were insignificant. However, near significance was shown by forb richness without a significant treatment-by-season interaction, $P = 0.07$. This suggests that burning as well as natural seasonality enriched the forb flora. The general trend was higher mean richness in the spring (14.2) than summer-fall (12.8) and in both burned areas (14.8–15) than the unburned area (10.6). These trends were related to the seasonal decline in forbs with their increase due to burning because overall species richness was strongly and significantly related to forb richness, not grass richness. There was no difference in species richness between the two burned areas, yet examination of particular species present in the treatment areas revealed differences that may be related, in part, to the unassessed preburn floras. Five species (three grasses and two forbs) were intercepted in the unburned area but not found in either burned area. The area burned once contained 15 species (2 grasses and 13 forbs) not found in either of the other areas. The area burned twice contained 12 unique species (1 grass and 11 forbs) (Figure 1 and Table 1).

Of 15 species unique to the once-burned area, 67% were warm-season plants and 33% cool-season plants. Whereas, of 12 species unique to the twice-burned area, 58% were warm-season and 42% cool-season. This is a more even proportion (Figure 2). The overall percentage of forb species was almost identical, 78% forbs in the once-burned area and 76% in the area burned twice.

The values calculated for percentages of grass versus forb species and cool- versus warm-season species cannot be analyzed statistically because of lack of preburn data. However, the numbers reveal trends that need to be analyzed after future burns. The majority of transects in the area burned once was sampled in the spring but has a lower average of cool-season plants than the twice-burned area, which was sampled primarily during the growing season. Examination of the ten dominant species in each treatment area reveals that the unburned area was dominated by over 50% occurrence of one grass species (*Stipa leucotricha*), while the remaining nine dominants each constituted less than 10% occurrence (Figure 3). Stipa leucotricha was also the dominant species in both burned areas but had less than a 20% occurrence (Figure 4 and 5).

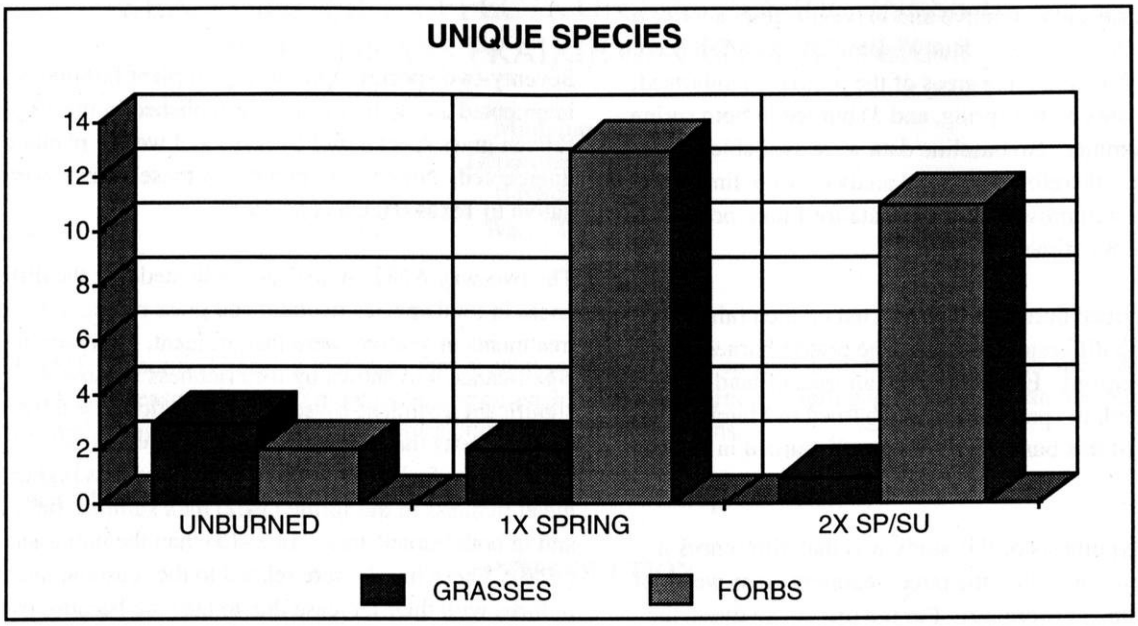

Figure 1. Number of grasses and forbs unique to each treatment area (Sp = spring, Sp/S = Spring/Summer).

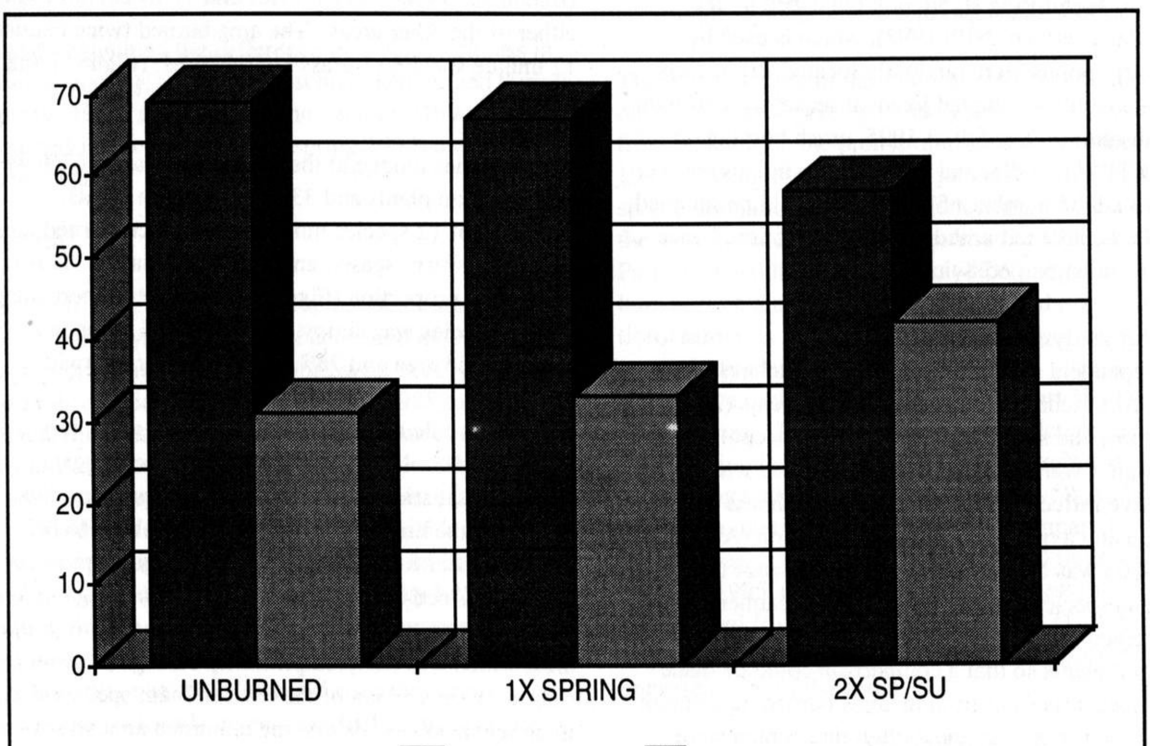

Figure 2. Percent of cool season vs. warm season species intercepted in each treatment area.

Table 1. Listing of unique grass and forb species for each treatment area.

	Grasses	Forbs
Unburned	*Elymus virginicus* *Panicum hallii* *Paspalum pubiflorum*	*Cocculus carolinus* *Heliotropium tenellum*
1X-Sp Burned	*Bouteloua hirsuta* *Dicanthelium linearifolium*	*Argythamnia mercurialana* *Castelleja indivisa* *Cirsium texanum* *Galium pilosum* *Hymenoxys scaposa* *Lindheimera texana* *Psoralidium tenuiflorum* *Ratibida columnaris* *Rudbeckia hirta* *Senna roemeriana* *Sherardia arvensis* *Solanum dimidiatum* *Thelesperma filifolium*
2X-Sp/S Burned	*Tridens albescens*	*Aster ericoides* *Dyschoriste linearis* *Eriogonum longifolium* *Gaura suffulta* *Liatris mucronata* *Phlox roemeriana* *Phyla incisa* *Physalis pumila* *Salvia engelmannii* *Salvia texana* *Stillingia texana*

DISCUSSION

The results of the analyses in this study were consistent with past research, which indicates that species richness increases with burning (Howe 1994a). The research at MNSP indicated that differences in species richness of burned and unburned plots in the mixed-grass prairie were greatly determined by forb richness, not grass richness. The difference in species richness observed was due to burning and not to season of burn. If future management practices relied on this information only, burning could be conducted at any convenient time during the year. Closer examination of the species present in each treatment area indicates that although species richness might not be significantly different between the two burned areas, there was a difference in the actual species composition (Appendix A).

Examination of annuals versus perennials revealed that of the nine annual species intercepted on the prairie, three species (*Bromus japonicus*, *Monarda citriodora*, and *Croton texensis*) were found in each of the three treatment areas. Additional annual species intercepted were *Castelleja indivisa*, *Sherardia arvensis*, *Plantago helleri*, *Lupinus texensis*, *Agalinis fasiculata*, and *Phlox roemeriana*. *Castelleja indivisa* was intercepted only in the once burned area and *Phlox roemeriana* was intercepted only in the twice-burned area. The remaining plants intercepted were all perennial species. Burning may only have decreased competition, allowing species that were already present in the seed bank to proliferate. The difference in the species present in the two burned areas possibly resulted from the season of burn, the growing season burn allowing cool season vegetation to proliferate and the dormant season burn favoring warm

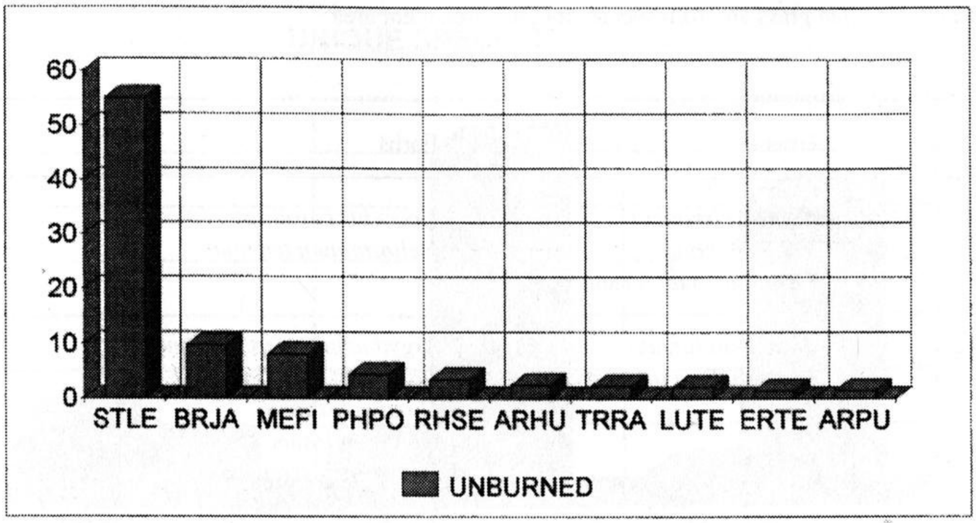

Figure 3. Percent occurrence of species intercepted in unburned area.

Species codes: STLE -*Stipa leucotricha*
BRJA - *Bromus japonicus*
MEFI - *Meximalva filipes*
PHPO -*Phyllanthus polygonoides*
RHSE - *Rhynchosia senna*
ARHU - *Argythamnia humilis*
TRRA - *Tragia ramosa*
LUTE - *Lupinus texensis*
ERTE - *Erodium texanum*
ARPU - *Aristida purpurea*

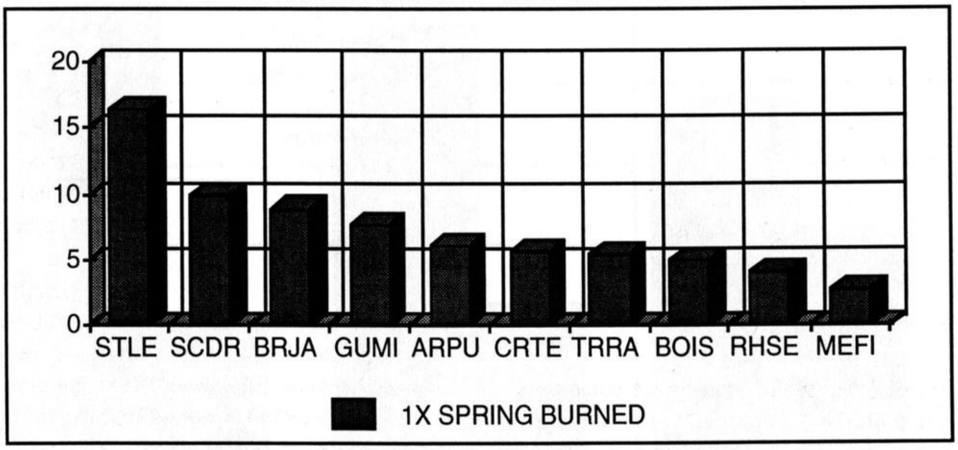

Figure 4. Percent occurrence of species intercepted in 1X Spring burned area.

Species codes: STLE -*Stipa leucotricha*
SCDR - *Scutellaria drummondii*
BRJA - *Bromus japonicus*
GUMI - *Gutierrezia microcephala*
ARPU - *Aristida purpurea*
CRTE - *Croton texensis*
TRRA - *Tragia ramosa*
BOIS - *Bothriochloa ischaeum*
RHSE - *Rhynchosia senna*
MEFI - *Meximalva filipes*

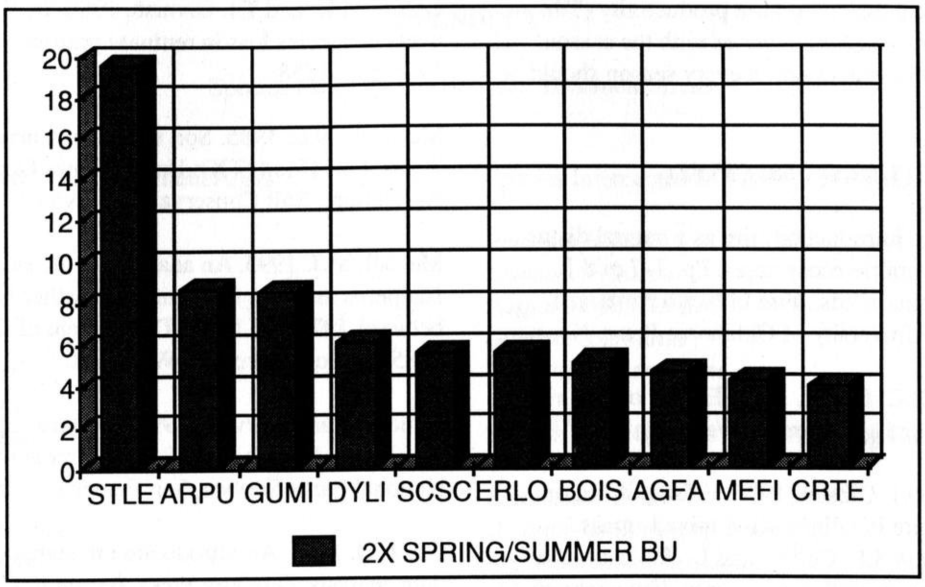

Figure 5. Percent occurrence of species intercepted in 2X Spring/Summer burned area. Species codes:
STLE -*Stipa leucotricha*
ARPU - *Aristida purpurea*
GUMI - *Gutierrezia microcephala*
DYLI - *Dychoriste linearis*
SCSC - *Schizachyrium scoparium*
ERLO - *Eriogonum longifolium*
BOIS - *Bothriochloa ischaeum*
AGFA - *Agalinas fasiculata*
MEFI - *Meximalva filipes*
CRTE - *Croton texensis*

season species (Reichman 1987, Glenn-Lewin et al. 1990, Howe 1994b).

Prior constraints on the experimental design prevented a statistical analysis of changes that might have been apparent between the areas burned in different seasons. The lack of statistical evidence should not overshadow the possible implications of this study. Many of the plots in the different treatment areas were located as close as 122 m within the same soil type, topography, and hydrography. This is a small prairie (32 ha) and it is probable that in the absence of fire the burned areas would have a very similar species composition as the area left undisturbed.

It is reasonable to expect an area burned in the spring and during the late growing season would support a greater species richness, yet the results of this study were inconclusive concerning both increased species richness between the two burned areas and changes in species composition within these areas. The mean species richness of both burned areas was approximately 15. The difference in species between these areas was not in species richness but in what species were present (Appendix B).

CONCLUSIONS

There are areas of essentially undisturbed prairie remaining in the U.S. and these reserves provide valuable information (White 1984), yet what remains today is not indicative of the original prairie (Pyne 1984) and therefore cannot serve as a model for prairie restoration. Research indicates that many factors (including climate, presence of grazers, burn regime, and geology) played a role in forming and maintaining the past prairie (Pyne 1984, Collins and Barber 1985, Smeins 1986, Collins 1990, Howe 1994b). Because fire was important to the maintenance of the historic prairie, it has become a very important restoration tool (Pyne 1984, Collins 1990, Howe 1994b). Indiscriminate and exclusive use of fire, particularly in the dormant season, is not the solution to restoring a prairie. Research efforts should therefore concentrate on studying the disturbance effects, particularly burn season, on species richness (Howe 1994b, Leach and Givnish 1996, Tilman 1996) and on the differences in species composition. If burning is to be a part of the management regime, the implications are that alternating the season of burn will increase forb richness, and possibly species composition, thereby increasing general species richness and prairie productivity (Tilman et al. 1996). Prairie vegetation varies with the season, and preserving the entire ecosystem in every season should be a priority.

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APPENDIX A

Species Comparisons Between Treatment Areas

Species Intercepted In All Treatment Areas

Aristida purpurea
Bromus japonicus
Panicum hallii
Stipa leucotricha
Argythamnia humilis
Asclepias asperula
Convolvulus arvensis
Croton texensis
Erodium texanum
Gutierrezia microcephala
Monarda citriodora
Opuntia sp.
Phyllanthus polygonoides
Sida filipes
Tragia ramosa

Species Intercepted In Never Burned Area And 1X Spring Burned Area

Evolvulus pilosus
Lupinus texensis
Matelea biflora
Plantago helleri
Rhynchosia senna
Solanum eleagnifolium

Species Intercepted In 1X Spring Burned Area & 2X Spring/Late Summer Burned Area

Bothriochloa ischaemum
Bothriochloa longipaniculata
Bouteloua hirsuta
Bouteloua curtipendula
Dicanthelium linearifolium
Erioneuron pilosum
Muhlenbergia capillaris
Schizachyrium scoparium
Agalinis fasiculata
Brickellia eupatorioides
Hedyotis nigricans
Hymenopappus scabiosaeus
Juniperus ashei
Krameria lanceolata
Lygodesmia texana
Schrankia roemeriana
Scutellaria drummondii
Verbena bipinnatifida
Verbena halei

Species Intercepted In The Never Burned area Only

Panicum hallii
Elymus virginicus
Paspalum pubiflorum
Cocculus carolinus
Heliotropium tenellum

Species Intercepted In The 1X Spring Burned Area Only

Bouteloua hirsuta
Dicanthelium linearifolium
Argythamnia mecurialana
Castelleja indivisa
Cirsium texanum
Galium pilosum
Hymenoxys scaposa
Lindheimera texana
Psoralidium tenuiflorum
Ratibida columnaris
Rudbeckia hirta
Senna roemeriana
Solanum dimidiatum
Sherardia arvensis
Thelesperma filifolium

Species Intercepted In The 2X Spring/Late Summer Burned Area Only

Tridens albescens
Aster ericoides
Dyschoriste linearis
Eriogonum longifolium
Gaura suffulta
Liatris mucronata
Phlox roemeriana
Phyla incisa
Physalis pumila
Salvia engelmanii
Salvia texana
Stillingia texana
Yucca sp.

APPENDIX B

ANOVA and MSR Table

Species Information for 2-way ANOVA and Multiple Regression Analyses

	TREATMENT	TOTAL RICHNESS	GRASS SPECIES	FORB SPECIES	1Spr,2Sum-Fall
1	1	10	4	6	1
2	1	12	5	7	1
3	1	14	4	10	1
4	1	10	4	6	2
5	1	7	3	4	1
6	2	14	4	10	1
7	2	8	3	5	2
8	2	17	3	14	1
9	2	11	1	10	1
10	2	14	4	10	2
11	2	16	5	11	1
12	2	18	4	14	1
13	2	20	6	14	1
14	2	16	2	14	1
15	3	16	2	14	1
16	3	15	4	11	2
17	3	19	4	15	2
18	3	12	5	7	2
19	3	12	5	7	2

Treatment 1 = Unburned area
Treatment 2 = 1X Spring burned area,
Treatment 3 = 2X Spring/Summer burned area.

THE GREENING OF PSYCHOLOGY AND EDUCATION

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The end of the twentieth century has caused a growing number of individuals to realize that environmental problems are of such magnitude and complexity that we need to fundamentally re-examine our attitudes, values, perceptions, and worldview. A basic critique of the present situation is that western culture, since Socrates, has primarily been anthropocentric, or human centered. Our philosophic, scientific, and religious traditions have seen humans as the epitome of creation, far superior to all else, who have the right to use creation for their own benefit.

The most poignant contrast to our western worldview is that of primal cultures, including Native Americans. In these cultures the cosmos is alive and spirited, to be treated with humility and respect as another being. Everything organic and inorganic is sacred, "We are all related" the Lakota Sioux say.

There have been exceptions in the evolution of the basic western worldview (Sessions 1991) and a growing number of philosophers, termed "deep ecologists," have risen to challenge the dominant positions. They call for an ecocentric, or ecological approach to our interactions with the surrounding world, considering the nonhuman world to be valuable in and of itself. They believe we are capable of identifying far more deeply with the world around us: an identification that will spontaneously lead us to appreciate and defend this world (Fox 1991).

Carl Sagan, co-chair of the Joint Appeal by Science and Religion for the Environment, presented a petition in 1992 stating:

> ...the environmental problem has religious as well as scientific dimensions... As scientists, many of us have had a profound experience of awe and reverence before the universe. We understand that what is regarded as sacred is more likely to be treated with care and respect. Our planetary home should be so regarded. Efforts to safeguard and cherish the environment need to be infused with a vision of the sacred. At the same time, a much wider and deeper understanding of science and technology is needed. If we do not understand the problem it is unlikely we will be able to fix it. Thus there is a vital role for both science and religion.

There is a person within our western tradition who addresses these issues but who has largely been ignored. His concepts of the psyche and its connection to the broader world have been out of keeping with dominant scientific and psychological perspectives. Carl Jung, a Swiss psychiatrist (1875-1961) and contemporary of Sigmund Freud, has been gaining recognition since the rise of feminism, a more ecological world view, alternatives to the strict medical models of health, psychoneuroimmunology research, eastern influences in our culture, the release of the psychological community from the Procrustean bed of behaviorism, and the reductiveness of Freudian theory. Jungian analysts such as James Hillman (1992) and USDA scientists like Herbert Schroeder (1991) have articulated some of the dimensions of Jungian psychology that are pertinent to altering our perspectives on the environment. This paper will provide a basic overview of Jungian theory as it pertains to our relationship with nature. Jung's model of the psyche, largely born out of neglected elements of western cultural tradition, presents a bridge to the Native American sense of connection to the land and offers a model for an ecocentric academic curriculum. The metaphoric roots of this model will be presented by examination of the Greek god Hermes, one of the 12 Olympian gods.

Jung's Connection to Nature and the Underground God

Jung said that a person not connected to the land is neurotic. Jung had a profound sense of connection to the land that was incorporated into his psychological theories and practice. He provided a moving account of how "big dreams" and visions guided his life and theory formation in his autobiography, *Memories, Dreams, Reflections*, finished shortly before his death in 1961 *(Jung, 1965)*. Jung developed a mystical sense of the land while growing up in rural Switzerland at the end of the last century. He had strong childhood memories of the awe and beauty of the Swiss landscape.

Jung's psychological development contributed significantly to his creation of a worldview radically different from the prevailing western perspective. He was a lonely, sickly child. Between ages three and four he had the first dream he could remember that had a profound impact on his life. It was a nightmare about a huge phallus atop a golden throne in an underground cave. It had a single eye on top that gazed upward into an aura of brightness associated with it. Just as he became terrified that this object would attack him, his mother called out, "Yes, just look at him. That is the man-eater!"

Only much later did Jung realize that the object was a phallus and it was decades before he understood it to be a ritual phallus: an object by itself on a throne, indicative of a sacred object. The light associated with it is related to the etymology of the word phallus—shining, bright.

Jung had learned a childhood prayer about Christ taking little children unto himself, which he mistook as Christ devouring them so that Satan could not devour them. He associated this with talk about Christ taking people to himself when they disappeared into the earth at graveside funerals presided over by his minister father. The man-eater of his nightmares thus became connected with a dark lord Jesus and the phallus.

The dream haunted Jung for years. It became an enormous dark secret he could share with no one and it isolated him even more. He said of this dream only years before his death:

> The phallus of this dream seems to be a subterranean God "not to be named," and such it remained throughout my youth. ... Who brought the Above and Below together, and laid the foundation that was to fill the second half of my life with stormiest passion? Who but that alien guest who came both from above and from below? Through this childhood dream I was initiated into the secrets of the earth.
> (Jung 1965)

This experience of a subterranean God "not to be named" became the foundation of Jung's sense of the spirit in nature, of god in matter, and a psycho-spiritual interest in alchemy.

The appearance of sacred, mythic motifs in a child's dream, which Jung observed as a psychiatrist, was evidence for him of a mythic dimension in every human psyche, a level he called the "collective unconscious." Archetypal dreams in childhood often set the course of one's entire life.

Jung developed a passion for being alone during his school years and found solace in nature.

> Nature seemed to me full of wonders, and I wanted to steep myself in them. Every stone, every plant, every single thing seemed alive and indescribably marvelous. I immersed myself in nature, crawled as it were into the very essence of nature and away from the whole human world. (Jung, 1965)

The Theory of Archetypes and the Natural World

Jung entered the infant field of psychiatry at the end of the nineteenth century because he saw it as the empirical field common to biological and spiritual facts, "where the collision between nature and spirit became a reality." In psychiatry the subjective dimension of the work had to be recognized. Jung's extensive work with schizophrenics provided further evidence of a mythic dimension in the human psyche, where even twentieth century schizophrenic men and women believe they are God or the Devil and live out mythological motifs.

Jung became a member of Freud's inner circle in the early 1900s. He broke away from Freud over what he thought was Freud's overemphasis on sexuality and his reductive treatment of the human psyche. Jung felt that sexuality had an impersonal, sacred dimension that Freud missed. Ostracism from the Freudian circle threw Jung into great despair, forcing him to discard all theories and enter a relentless, open pursuit of the products and fantasies arising from his own unconscious. He did this by playing in the sand, painting, sculpting, writing, paying avid attention to dreams and visions, and by consciously interacting with spontaneous unconscious images which he called "active imagination." The experience was direct, often overwhelming and frightening and led into the depths of the psyche familiar to shamans and mystics. Paranormal events were frequent, where the borders between inner and outer reality merged.

Jung discovered that the mythic stories are alive in us today. He called the particular elements of the shared mythic levels the "archetypes." Archetypes are constitutional, basic ways of perceiving and behaving in the world —the bedrock of the psyche shared by all. Archetypes are the themes and types of images that recur throughout human existence across cultures and time—the Divine Child, the Wise Old Man, Mother Earth, the Trickster, etc. George Lukas's Star Wars trilogy borrowed heavily from the archetype of the Hero as developed by Joseph Campbell in his classic book, The Hero with a Thousand Faces.

Of interest to environmentalists is Jung's concept of an archetype in every person he called "the indigenous one within," a primal level of the psyche Jung liked to call the "Great Man" or "the two million year old man within." This archetype is at the foundation of every human psyche, where the psyche borders on the realm of the animal spirits in mythic connection with the world (Jung 1964, 1965). In Greek mythology it is Hermes who borders on this realm at his "lower" level (Kerenyi 1976). A deep spiritual relationship with nature and reverence for the land is potential in every human. Like every archetype, it has to be constellated by appropriate experience in the world (Jung 1980). A dimension of this archetypal level of the psyche is what E.O. Wilson referred to decades later as "biophilia," an innate love of nature.

What Jung had discovered on his journey was a light in the darkness, a light out of the unconscious foretold by the light associated with the underground phallic image of his childhood nightmare. The procedures used in his therapy for approaching and working with products of the unconscious were those he developed on his personal journey of the mind. Religious attention to the products of the unconscious has the subjective experience of:

> The feeling that some suprapersonal force is actively interfering in a creative way. One sometimes feels that the unconscious is leading the way in accordance with a secret design. It is as if something is looking at me, something that I do not see but sees me - perhaps the Great Man in the heart, who tells me his opinions about me by means of dreams. (Von Franz in Jung 1964)

Jung associated the creativity of dreams with the creativity of nature:

> So at the source of the dream there is a creative mystery which we cannot rationally explain. It's the creativity of nature. It's the same creativity which has created what man could not invent: the millions of species of animals and flowers and plants on the earth. The dreams are also like flowers or plants. They are something unique which we can only marvel at. (Jung 1964)

The Significance of Animals in Dreams

Jung placed particular importance on animals in dreams. He suggested that we need an animal imagination to be in our bodies (Jung 1976b) and he felt that it was important to become familiar with animals that appeared in our dreams in order to assimilate the nature of that particular animal. To do that one has to imagine putting oneself inside the animal, not judging it by outward appearances (Jung 1976a).

Jungian analyst James Hillman admits he takes animals in dreams:

> ...unvaryingly as the most significant element because it is the place where psyche opens into forms, beings of mystery and beauty who are creatures as we are and yet remain 'other'. (Hillman 1983)

In the dream world ".... Their souls and ours meet as images.... the dream itself encloses us protectively in the saving ark, in the originating garden, and there in the dream, we may recover the habits of the cat and mouse, the knowledge of the pig, the animal coat, the animal tail, the animal eye." (Hillman 1983)

In our dreams, as in primal cultures, the animals don't represent gods, they are the gods. There is a divinity associated with them. The divine is partly animal and the animal, partly divine. The animal is sacrificed at an altar as a means of keeping the god alive (Hillman 1988).

The divine aspect of animals becomes apparent by the frequent appearance of the Self in the form of an animal in dreams, called the theriomorphic form of the Self. The Self is what Jung called the archetype of wholeness, the center and centering force in the psyche that includes the conscious and unconscious realms. This inborn psychic trait produces a personal image and experience of what gets expressed at the cultural level as Jesus, Buddha, Wakantanka, Yahweh, etc. The theriomorphic form the Self takes in dreams is often that of the elephant, horse, bull, bear, white and black birds, fishes, and snakes (Jung 1959b). This is especially true of animals in big dreams, or numinous dreams—dreams that feel special with an inner light that leaves the dreamer with a sense of wonder and awe. It is particularly important with such dreams and images not to reduce the animal in the dream to an instinct, a function or association such as intuition or gluttony, or a piece of family history in an oedipal conflict. The ideal is to let the image work on one, to hold it in consciousness, and let the image revamp one's conscious position. This can be done by reading about the animal, collecting pictures and stories and items associated with it, discovering how it has been portrayed in myths and religions around the world, and visiting its natural habitat. The process is illustrated by Herb Martin, Jr. in an article entitled, "Running Wolf: Vision Quest and the Inner Life of the Middle School Student" (Martin 1988). Dr. Martin explains how he transformed a recurring childhood nightmare about wolves into what Native Americans would call a spirit animal guide. An example of how a powerful dream of wolves helped to expand the consciousness of an adult is presented by Herb Schroeder of the North Central Forest Experiment Station in Chicago in "Seeking the Balance: Do Dreams Have a Role in Natural Resource Management" (Schroeder 1996).

Synchronicity: a Radical Relationship with the World

Jung's most radical statement of a connection between inner and outer reality is his concept of synchronicity. Jung noted that when archetypal constellations occur, synchronistic events are more likely to happen. A minor example of synchronicity would be of thinking of someone you hadn't thought of in years and the phone rings and it is that person on the line. The outer world then seems to mirror inner psychic events. Jung believed, as a result of his own and his patient's experiences, that there was a dimension of the psyche outside of time and space. Synchronistic phenomena seem to indicate that the nonpsychic can behave like the psychic and vice-versa without there being a causal connection between them. In the background of the empirical world there is an identity of the psychic and the physical—they are two sides of the same coin. Archetypes have a psycoid dimension, a "just so," a priori nature that functions to organize the psyche as well as nonpsychic activity. Such phenomena are an integral part of a primal culture's experiences and often occur around big dreams and numinous dreams of animals even in twentieth century individuals. All primal cultures practiced means of deliberately putting one into states of consciousness where the boundaries between the inner and outer world would loosen. Such practices include vision quests, chanting, fasting, sweat lodges, hallucinogenic plants, etc. (Metzner 1993). Animals often appear to us at such times or behave in unusual ways, indicating that they may be our spirit animal or spirit guide. These helpful animals are presented in fairy tales and legends and often appear in dreams (Jung 1959a).

Alchemy, the post-Christian Unconscious and Nature

After Jung's prolonged encounter with the deeper realms of the unconscious following his split with Freud, he discovered parallels to his experience in neglected areas of western culture, most notably in alchemy. Jung became an expert on alchemy, using it as his main symbolic system for working with the psyche (Jung 1953, 1963, 1967). Alchemy had its roots in the early Greek Gnostic tradition of a direct experience of God. It engaged the minds of some of the brightest people in Europe, including Isaac Newton. Jung understood alchemy to be a psycho-spiritual exercise dealing with the deep processes of psychic transformation. Most alchemists realized they were not literally trying to turn base lead into gold. "Our gold is not the vulgar gold" they proclaimed. Jung recognized the alchemists as being the first modern depth psychologists, projecting the contents of a post-Christian collective unconscious into their alchemical vessels and retorts. Since they did not understand the chemical reactions they were observing, their statements about the chemical processes can be taken as naive, subjective confessions of the inner workings of their psyches. They were not looking for God in the heavens, but for the spirit in matter. Their process led them to the rejected elements of Christian culture— the body, the feminine, sexuality, sensuality, and nature. Their great work, usually done alone with religious care over a period of years, involved elaborate fantasies about what they perceived happening to "rejected matter" as it underwent various physical and chemical transformations. They had the experience of "as above, so below"—that inner and outer were related in what Jung called the psychoid dimension of the archetypes. Many of the alchemical motifs and processes appear in fairy tales. A substantial part of the training to become a Jungian analyst involves working with fairy tales. This helps develop a symbolic eye and a feel for the deep, transformative processes in the human psyche.

Hermes as the Missing Link to the "Natural"

The god of the alchemists was the Roman god Mercury, known as Hermes in Greek mythology. To understand Hermes is to appreciate alchemy and the archetypal core of Jung's psyche, theories, and his connection to nature. Myths of Hermes can be interpreted as the ancient Greeks' unconscious recognition of the need to stay in intimate relationship with the myth and sacred dimensions of the body, the feminine, and the natural world.

The Classic Greeks knew the gods didn't literally exist, but they were more than real, just as story and myth are the best presentations of the human condition. Each god or goddess represented a particular way of being in the world; a world brought to light by them, of which they were the root, or distilled essence of and inner light to. They were like comprehensive ideas that enclose us and create worlds by determining how we perceive and respond to the world—"archetypes" as Jung called them.

Hermes has been called the god of the unconscious because his main attributes are associated with the unconscious, including its deeper, mythic dimensions. The attributes associated with the unconscious include Hermes being the god of the night, who brings dreams and leads the souls of the dead to Hades. He is quick, fleeting, unpredictable, and can't be pinned down. He is the god of becoming, the root of creation, and the god of boundaries, in-between states and illusion. He was worshipped mainly in the form of upright phallic stones. His phallic attributes associate him with primordial, archetypal masculine yang energy and the mythic dimension of Jung's childhood phallic nightmare. As the source, the seed out of which everything springs, he is also that which connects and interrelates everything (Kerenyi 1976). Hermes is the messenger of the gods and messenger between gods and humans. As such he is god of the link between the myths and our personal lives and the god of communication and association between dominant psychic elements, or worldviews. One of his emblems, the double snake caduceus (two snakes entwined about a staff) symbolizes the opposites in relation to each other—our western version of the Chinese yin-yang. He is god of rhetoric, persuasive talk, and diplomacy—knowing when to bend truth to facilitate communication. Hermes is master of wit, joyousness, and clever use of language, an archetypal image presented as Mercutio in Romeo and Juliet.

The main mythic presentation of Hermes is Homer's "Hymn to Hermes" (Boer 1970). Day-old Hermes, a son resulting from an affair between Zeus and a nymph, cleverly steals 50 of Apollo's cattle and sacrifices 2 of them in equal parts to all 12 Olympian gods. Hermes is reconciled with his brother Apollo when he gives Apollo the lyre he has created from a turtle and sings him a song of all the gods and goddesses, their attributes and their stories. Apollo in turn gives Hermes domain over cattle and the animals; the wand of fame, fortune, and messenger; and recognition as the only messenger to Hades. The two swear to be the best of friends after Hermes promises never to steal from Apollo again.

Hermes thus provides a link upward to Apollo's realm of reason, far-sightedness, clarity, and cleanliness, rationality, and intellect. However, he also provides a link downward to the nymphs and satyrs, the body, sexuality, and "not so nice" aspects via the reality of myth. The Greeks succeeded in delineating two distinct and interrelated realms of human existence. They linked back to their primal roots at a time when history, math, science, and the written tradition were being established in western culture. They offer our present western culture a mythic model for our task today.

The Greening of Psychology

Jungian psychology incorporates this hermetic perspective that can offer a model, a framework, a worldview of the human psyche and its relationship to the environment that is holistic and integrative. For psychologists and therapists it brings a "feel" for the symbolic, imaginal, creative, spiritual, and natural elements in people's lives and dreams. The way a therapist works with dreams and the unconscious can help connect a person to the environment and develop a sense of place. Only if therapists have had personal experiences of these domains and the workings in their own psyches can they serve as soul guides to others.

The Jungian approach to working with dreams, life-stories, significant events, and overwhelming experiences helps link the personal to the mythic; helps us to see ourselves as both unique and universal, temporal and eternal. Expanding and amplifying important elements of dreams and images helps re-orient our consciousness, brings insights, and allows us to be influenced by them. These same approaches aid in linking us to plants, animals, and land and cultivate a sense of place. Dr. Schroeder of the USDA Forest Service in his article, "The Tree of Peace: Symbolic and Spiritual Values of the White Pine" (Schroeder 1992), focuses on Iroquois myths about the white pine as an archetypal image of peace and wholeness, the tree as Self as seen in many parts of the world. His article helps us appreciate the spiritual and symbolic importance of trees in general and the white pine in particular. We can connect to environments and elements within environments at a more basic level by working with dreams about that environment, reading myths and stories about it, viewing or doing art work associated with it, imaginally and symbolically developing elements within that environment, creating or listening to music inspired by it, and studying scientific material on that environment (Merritt 1994).

Aphrodite as the Soul of the World

James Hillman (1992) has developed a sophisticated approach to working with images and the gestalt of an image to accentuate its impact and to relate to it in a deeper, more meaningful manner. One of his approaches is to return to the Neo-Platonic notion of Aphrodite as the anima mundi, the soul of the world. From Aphrodite's perspective/world view, the soul of an image or object is the degree to which it fascinates the psyche. Images and objects are to be approached with a feeling, imagining heart, as a lover to a beloved. This intriguing approach can help connect one to the natural world.

Weather can be related to in this manner. Weather such as we have in the Midwest metaphorically presents the entire range of psychological states. Joseph Campbell recognized the analogy of the seasons to the human life cycle as being one of the most universal analogies. The ancient Chinese text, the I Ching (Wilhelm 1950) offers many weather and seasonal metaphors to convey its meanings, and presents an invaluable tool for developing a meaningful relationship to weather and climate, particularly in the Midwest.

The Greening of Education

A hermetic approach is needed in our educational systems. A Hermes approach is an ecological approach with the different disciplines being appreciated and related to each other. Hermes offers a mythic model to guide us—all disciplines are to be treated equally, one is not more important than the other. Science is a legitimate and important discipline but has imbalanced our education and society (Merritt 1988). A psychological rule of thumb is that which is neglected or not honored goes into the unconscious and trips us from behind, or degenerates into pathology. Teaching and education cannot overlook the importance of stories, myths, dreams, and music. In no area is this more important than environmental education.

Equally vital is a re-education on how we got to the present predicament of our highly dysfunctional relationship to the environment. We must re-examine the evolution and development of our religions, economic systems, science, and philosophy. Jung provides valuable insights and alternative perspectives by which to frame this study. It is a world view that picks up neglected elements within our western tradition that can help us appreciate and begin to experience something of the Native American sense of connection to the land to which "We are all related". It offers a response to Carl Sagan's plea for the development of a sacred sense about the environment to serve as a base for values and action.

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STATUS OF LEPIDOPTERANS ASSOCIATED WITH PRAIRIES IN OHIO

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ABSTRACT: The Ohio Survey of Lepidoptera, conducted by The Ohio Lepidopterists, provides excellent baseline data pertinent to distribution of butterflies and moths in Ohio. Many of this survey's data from Ohio's prairie remnants hinted that lepidopterans, in addition to plants, share affinities with prairie habitats to the west of Ohio, thus supporting the concept of Transeau's prairie peninsula. Forty-one species of moths that are specialists of prairies in Ohio, including 19 species newly recorded from the state, were recorded from 199 samples, taken from 1992 through October 1996, at several prairie sites in Ohio: Huffman Prairie, Greene County; Killdeer Plains Wildlife Area, Wyandot County; Resthaven Wildlife Area, Erie County; Irwin Prairie State Nature Preserve, Lucas County; Kitty Todd Preserve, Lucas County; and Oak Openings MetroPark, Lucas County Resource managers at the Ohio Chapter of The Nature Conservancy and the Ohio Department of Natural Resources, Division of Wildlife, responded to the new information about insects by adapting management practices to promote fully functioning prairies of animals and plants.

Key words: prairie, Ohio, Lepidoptera, Huffman Prairie, Resthaven Wildlife Area, Killdeer Plains Wildlife Area, Irwin Prairie State Nature Preserve, Kitt Todd Preserve, Oak Openings MetroPark

INTRODUCTION

Insects comprise the largest number of species on Earth (May 1992), yet they are rarely considered in conservation decisions. They are the most numerous, as individuals, and they comprise the greatest biomass of all living animals on the planet. They comprise more than one- half the species of all living organisms, inhabiting nearly every niche, and exhibiting nearly every life style on Earth (Borror et al. 1989), and insects probably represent the bulk of the world's imperiled species.

Lepidoptera is the second largest order of insects. Because most lepidopterans are herbivores, their presence or absence in a habitat is directly related to phytogeography (Dana 1983, Panzer 1995). There is growing evidence that the evaluation of the health of a community of local Lepidoptera can be a meaningful indicator of the general health of a particular ecosystem (Kremen 1992). In spite of their importance, a dearth of papers has been published about the distribution and abundance of Lepidoptera that are associated with or restricted to prairies. Most species of moths associated with prairies, including those reported here, do not have common names.

A great impetus to the study of Lepidoptera in Ohio was the formation of The Ohio Lepidopterists in 1979. With 360 members, the goals of this organization are to promote interest in, provide information on, and increase the knowledge of Lepidoptera in Ohio and neighboring states. The Ohio Lepidopterists contracted with the Ohio Department of Natural Resources (ODNR), Division of Wildlife, to conduct an Ohio Lepidopteran Survey (Case and Fritz 1985, Rings et al. 1992), after which an understanding of Ohio's lepidopteran fauna increased at a dramatic rate (Iftner et al. 1992). The six-year effort, from 1986 through 1992, produced a database with over 96,000 records of butterflies and moths from Ohio, representing specimen records from 3800 localities in the state. One hundred and fifty-one collections were examined for records.

The lepidopteran fauna of Ohio is as well known as any state in the U.S. The microlepidoptera, as classified by McDunnough (1939), are usually overlooked in faunal surveys because of their small size and difficulties with obtaining identifications. The Ohio Survey of Lepidoptera greatly benefited by data from the extensive collection of Lepidoptera assembled by Annette Francis Braun, a prominent microlepidopterist from Cincinnati, Ohio (Stein 1988, Solis 1990).

The concept of Transeau's prairie peninsula (1935) presents an excellent opportunity to examine the distribution of Lepidoptera relative to a mosaic of unique vegetational communities in Ohio. Not only should Ohio's relict prairies share suites of plants with states to the west of Ohio, but Ohio's prairies should also have disjunct populations of insects that are normally found in environs far to the west of the state. For example, *Tarachidia binocula* (Noctuidae) is recorded from three prairies in Ohio. It has not been recorded from Indiana nor Illinois and is known only from prairies in Wisconsin. It can be common in prairie habitats in states west of the Mississippi River.

Correlations of distributions of Lepidoptera, geology, soils, and plants were shown and discussed by Iftner et al. (1992) and Rings et al. (1992). Preliminary results of an intensive inventory at Huffman Prairie, near Dayton, Ohio, reported several examples of prairie specialist species (Metzler and Zebold 1995). The inventory of Huffman Prairie continued through 1996. Inventories at other prairies in Ohio were begun in 1994 and 1995 (Tables 1 and 2).

Lepidoptera respond directly to habitat size, past history of degradation, and management practices, such as burning (Dana 1986, Dana 1991, Miller 1979, Panzer 1988, Van Amburg et al. 1981, Swengel 1996). With these factors in mind, optimum strategies and disciplines for the management of wildlife resources need to be developed on a continuous basis to obtain the best possible balance of healthy flora and fauna (Hafernik 1992). The goals of the research at Huffman Prairie, Killdeer Plains Wildlife Area, and Resthaven Wildlife Area included making recommendations for managing the habitats to maximize protection for the lepidopteran species, especially species listed as endangered in Ohio by the ODNR, Division of Wildlife, in 1991 (Ohio Administrative Code 1501:31-12-01).

Table 1. Name and location of Ohio prairies that were sampled for moths.

Ohio County	Name of Prairie	No. of sample sites/prairie	Years that samples were taken
Erie	Resthaven Wildlife Area	2	1995-1996
Greene	Huffman Prairie	3	1992-1996
Lucas	Irwin Prairie State Nature Preserve	1	1995-1996
Lucas	Kitty Todd Preserve	1	1995-1996
Lucas	Oak Openings Metro Park	1	1995-1996
Wyandot	Killdeer Plains Wildlife Area	4	1994-1996

Table 2. Number of samples for each Ohio prairie that was sampled for moths, listed by sampling method. bl = blacklight trap, mt = malaise trap, bt = bait, pt = pheromone trap, bn = butterfly net.

Name of Prairie	No. of sample days in 1992	No. of sample days in 1993	No. of sample days in 1994	No. of sample days in 1995	No. of sample days in 1996
Resthaven Wildlife Area	0	0	0	bl = 6	bl = 8
Huffman Prairie	bl = 10 bn = 21	bl = 18 bn = 18	bl = 24 mt = 6 bt = 4 pt = 3	bl = 11 mt = 1 pt = 5	bl = 2 6mt = 2
Irwin Prairie State Nature Preserve	0	.0	0	bl = 2	bl = 5
Kitty Todd Preserve	`0	0	0	bl = 2	bl = 5
Oak Openings Metro Park	0	0	0	0	bl = 5
Killdeer Plains Wildlife Area	0	0	bl = 9	bl = 11	bl = 6

METHODS AND MATERIALS

Inventory protocols include blacklight traps, malaise traps, pheromone traps, baits, and insect nets. The various methods were selected to best sample all lepidopterans, including moths that fly during daylight hours.

A substantial number of moth species are active at night when they cannot be seen due to the darkness. These are best sampled by catching them in battery powered light traps. The traps were operated from dusk until dawn. The blacklight traps are modifications of the USDA design manufactured by the Elisco Company. The traps use 15-watt fluorescent blacklight bulbs. Malaise traps are designed to passively collect insects that fly past the trap (Townes 1972). Nothing is used to attract the insects to the malaise trap. The baits are mimics of substances that naturally attract lepidopterans to fermenting fruit. Some of the species of moths that come to baits are rarely, if ever, attracted to light. A bait mixture of decaying and fermenting fruit was applied to small synthetic sponges (3 inches x 6 inches x 1 inch). The sponges were hung from branches of nearby trees and bushes. Other species are attracted to pheromone traps, devises that contain a bait impregnated with commercially prepared synthetic chemicals which mimic sex attractant pheromones emitted by female moths.

The sites for the traps and baits were selected using a combination of criteria including consultation with land managers, ease of access by foot, flora near the sites, and gestalt. The sampling with a butterfly net at Huffman Prairie followed a transect that was designed to intersect with most of the plant communities in the prairie. Data pertinent to butterflies at the other sites are gleaned from the Ohio Survey of Lepidoptera's database.

The light traps were placed just before dark, and the samples were retrieved at dawn the following morning. The malaise traps were placed in the late afternoon. They were left in place for 24 hours, and samples were taken at dawn and in the late afternoon. The baits were placed just before dark. Samples were taken during the crepuscular hours until about mid-night, after which the baits were retrieved. Pheromone traps and butterfly nets were used during daylight hours.

All specimens of Lepidoptera were sorted to species and counted. The data were keyed into an IBM compatible computer using dBase® software. Each record, consisting of one or more specimens, includes the exact date and location of each species from each sample. The method of capture is included in the record. Many specimens, especially the smaller lepidopteran species, were pinned, mounted, dissected, and photographed for subsequent consultations with experts at the U.S. National Museum of Natural History, Washington, DC and Agriculture Canada's Centre for Biological and Land Resources, Ottawa, Ontario. All nonlepidopteran in the samples were stored in alcohol for subsequent study. Lists of species from Ohio's prairies were compared with data from the Ohio Survey of Lepidoptera, distributions of the species, larval hosts, and habitats of the species.

RESULTS

Forty-one species of Lepidoptera that are restricted to prairies in Ohio were recorded, in 199 samples, from 1992 through October 1996 (Tables 2 and 3). Nineteen of these species were recorded from Ohio for the first time. Eight hundred and fifty-five species of moths and 33 species of butterflies have been identified from the samples—the prairie specialists represent 5% of the species in the samples. None of the butterflies are restricted to prairies in Ohio.

Voucher specimens are deposited in the Dayton Museum of Natural History, the collection of The Ohio Lepidopterists at The Ohio State University Museum of Biological Diversity, The U.S. National Museum of Natural History, The Canadian National Collection, the Cleveland Museum of Natural History, The American Museum of Natural History, and the private collections of Eric H. Metzler and Roger A. Zebold. George Balogh, P.T. Dang, Donald R. Davis, Loran D. Gibson, Jean-François Landry, Ronald W. Hodges, Reed A. Watkins, and Donald J. Wright retained some specimens in exchange for expert identifications.

DISCUSSION

A prairie specialist Lepidoptera in Ohio is a species that occurs in Ohio's prairies because of the processes of Transeau's prairie peninsula. When Ohio was more xeric and the prairie habitats of the Great Plains extended east into central Ohio, species of plants and animals expanded their range eastward into the state. As climatic conditions changed and the prairie peninsula retreated, relict populations of plants and animals survived in the state. In Ohio, prairie plants and animals share affinities with states west of Ohio, where the plants and animals are not necessarily restricted to prairies. Except for anomalous habitats in Pennsylvania, New York, and other eastern states, the prairie peninsula did not extend northeast of Ohio. Neither did the prairie-associated plants and animals. I consider lepidopterans to be prairie specialists in Ohio if they meet the following criteria: 1) they have been recorded only in prairies in Ohio; 2) they have been recorded only in prairie habitats in states east of Ohio; 3) they have been recorded in prairie or prairielike habitats in states east of the Mississippi River and west of Ohio, or 4) larval hosts and nectar sources are restricted to prairies in Ohio. The lepidopteran species may not be restricted to prairies in states west of the Mississippi River. The definition of prairie includes all sites reported as such. None of the species reported here have common names.

The affinity of Ohio's relict prairies with habitats in states to the west of Ohio is supported, and the number of prairie

Table 3. List of prairie remnant dependent moths recorded in the samples. rwa = Resthaven Wildlife Area, hp = Huffman Prairie, ip = Irwin Prairie, ktp = Kitty Todd Preserve, oo = Oak Openings Metro Park, and kpwa = Killdeer Plains Wildlife Area.

Name of Species	Occurs in these Prairies	Newly recorded from Ohio?
Bucculatrix simulans	hp	yes
Bucculatrix staintonella	kpwa	yes
Caloptilia belfrageella	rwa	no
Agonopterix pteleae	hp	yes
Marmara leptodesma	kpwa	yes
Batrachedra praeangusta	kpwa	yes
Chedra inquisitor	kpwa	yes
Stereomita andropogonis	rwa, hp, ip, ktp, oo, kpwa	no
Aristotelia corallina	kpwa	yes
Aristotelia elegantella	kpwa	no
Aristotelia psoraleae	hp	no
Aristotelia salicifungiella	hp	yes
Gelechia lynceella	kpwa	no
Scrobipalpula artemisiella	hp	yes
Helcystogramma hystricella	hp, kpwa	no
Dichomeris costarufoella	rwa	yes
Acrolepiopsis leucoscia	hp	yes
Eucosma heathiana	rwa, hp	yes
Eucosma vagana	hp, kpwa	no
Eucosma matutina	hp	no
Eucosma giganteana	rwa, hp, kpwa	no
Eucosma bipunctella	rwa, kpwa	no
Eucosma bilineana	kpwa	no
Eucosma nandana	rwa, hp, kpwa	no
Eucosma fulminana	rwa, kpwa	no
Epiblema tripartitana	hp	no
Suleima helianthana	kpwa	no
Sonia canadana	hp	no
Dichrorampha sedatana	hp	yes
Platynota stultana	rwa, hp	yes
Aethes bomonana	rwa, kt, kpwa	yes
Aethes spartinana	rwa, kpwa	yes
Hysterosia villana	hp, kpwa	yes
Lychnosea intermicata	hp	no
Haploa reversa	hp, kpwa	no
Tarachidia binocula	rla, hp, kpwa	no
Tarachidia tortricina	hp, kpwa	no
Luperina stipata	rla, hp, kpwa	no
Papaipema beeriana	rla, kpwa	no
Papaipema silphii	rla	no
Tricholita signata	rla	no

specialist species of Lepidoptera recorded in Ohio was more than doubled. *Tarachidia binocula*, previously known from a single specimen from Resthaven Wildlife Area, was found in Huffman Prairie and is abundant in Killdeer Plains Wildlife Area. *Eucosma heathiana* (Tortricidae) was first recorded from Ohio in Huffman Prairie in 1992, and it was found at Resthaven Wildlife Area in 1996. *Aethes spartinana* (Tortricidae) was described from South Dakota where the larvae feed on *Spartina pectinata* (Gramineae). *Aethes spartinana* is common at Killdeer Plains Wildlife Area, and one specimen was taken at Resthaven Wildlife Area. *Spartina pectinata* is common in both of these prairies. Prior to its discovery at Killdeer Plains Wildlife Area, *Marmara leptodesma* (Gracillariidae) was only known from the type locality in Texas, and *Aristotelia corallina* (Gelechiidae), described from Mexico, was only known from the southwest U.S.

Hafernik (1992) correctly states that invertebrates, as the predominant organisms on earth, should have greater attention in conservation strategies. Hafernik's recommendations coincide with the revised paradigm in conservation biology proposed by Pickett et al. (1992) in which it is argued that the system and process, rather than species-level preservation should be examined. The prairie animals, as well as the prairie plants, should be studied, inventoried, and protected. Fry (1991), New (1991), Pollard and Yates (1993), Samways (1994), New (1995), and Pullin (1995) provide examples of strategies to conserve invertebrates. For purposes of studying biological diversity with animals, lepidopterans are a good choice because they are numerous, they are excellent indicators of specific habitats, and they are a valuable food source for birds and mammals. Compared to most other insects, lepidopterans have positive public appeal making it easier to gain support for their study.

Ohio's remnant prairies are small and fragmented. Assuming that prairie specialist species in the state are restricted to prairies in the eastern U.S., or that they are disjunct populations of western species, their occurrence in Ohio's remnant prairies supports Transeau's concept of a prairie peninsula. Their isolation from other naturally occurring prairies makes it highly improbable that insects from other locations could colonize these areas.

Three concerns pertinent to prairie management are noted. The first concern is the protocol for using fire as a management tool, the second is invasion of woody plants, and the third is manipulation of wildlife areas for sporting activities. Managers of Ohio's remnant prairies are diversifying their strategies to protect the complete suite of plants and animals that comprise the prairie ecosystem.

Resource managers regularly use fire for prairie management and restoration. The practice is predicated on the idea that fire, whether naturally occurring or set by humans, is an important factor in the maintenance of prairie habitat. In Ohio, fires for management purposes are used either in the early spring or late autumn following a hard frost, sometimes on an annual basis. Such use of fire does not mimic natural phenomena, thereby putting insects, which are vulnerable to fires, at risk.

The issue with fire is that in the original landscape disturbances were patchy. Even though the largest prairie remnants in Ohio are less than 100 acres, the discontinuity of burns must be maintained. A protocol for fire as a management tool should mimic naturally occurring fires. Natural fires burn in mosaics and leave unburned refugia for vulnerable animals. Resource managers should accommodate all plants and animals that are prairie specialists. Their survival in the remnants is as fragile as the prairies they inhabit.

The frequency of naturally occurring fires in Ohio's prairies is speculative, but the literature suggests that natural burns probably did not occur more often than one in five years at a given site. Costello (1969) vividly describes grassland fires, but their frequency may be from 5 to 30 years (Wright and Bailey 1982) depending on a variety of conditions. It is known that Native Americans burned grasslands to maintain openings, as frequently as every two years in Wood County, Ohio (Maryfield 1988), but there is little proof that Native Americans and early settlers routinely set fires (Russell 1983). At the most frequent, Ohio's prairies might have burned naturally every five years (Wright and Bailey 1982, Clark 1989).

The Ohio Chapter of The Nature Conservancy responded to the new information about insects. One of the study sites, Huffman Prairie, is located on Wright-Patterson Air Force Base near Dayton. Through a cooperative agreement with the Department of Defense, The Nature Conservancy provides recommendations to the base for restoration and management of Huffman Prairie. The Nature Conservancy used information provided by Metzler and Zebold (1995) to recommend a revised protocol for conducting prescribed burns. Previously, the prairie was either burned or mowed in its entirety on a nearly annual basis, beginning in 1984. The revised protocol recommends that only one quarter of the prairie is burned in any one year. Under the revised management strategy, each quarter of the prairie will be burned once every four years. Unburned areas will be left as refugia.

CONCLUSIONS

Without management, the isolated prairie remnants in Ohio would succeed to forested communities. This would not only change the composition of the vegetation, but could also change the composition of the lepidopterans from prairie specialists to woodland species. The Ohio Chapter of The Nature Conservancy and Wright-Patterson Air Force Base used data from the inventory to intensify removal of woody plants at Huffman Prairie. Fire would normally reduce the amount of woody vegetation. However, in years when a prescribed burn cannot be conducted, the designate unit will be mowed to temporarily suppress woody vegetation. In addition, the resource managers responded by removing woody plants through the selective use of herbicides.

The ODNR Division of Wildlife modified its manipulation of some plots in ways that accommodate the occurrence of prairie specialist species, and the Division of Wildlife routinely queries lepidopteran data when making management decisions. Management of Ohio's wildlife areas includes manipulation of the landscape for propagation of game animals. Food crops are planted and acreage is mowed to accommodate sporting activities. Prior to data from the Ohio Survey of Lepidoptera, Ohio's wildlife managers did not consider terrestrial insects in their management plans. The discovery of *Papaipema silphii* and *P. beeriana* at Resthaven Wildlife Area prompted the Division of Wildlife to remove additional prairie acreage from its crop rotation schedule. The discovery of *Tarachidia binocula, Luperina stipata*, and *P. beeriana* at Killdeer Plains Wildlife Area prompted the Division of Wildlife to look at activities pertinent to prairie acreage. Lepidopteran data were recently consulted before making a decision about drainage ditches and to modify plans for a major wetland improvement project.

A Partnerships in Wildlife Grant from the U.S. Fish and Wildlife Service to the Wisconsin Department of Natural Resources for inventories of insects of northern tallgrass prairies facilitated expansion of the inventory of moths in Ohio's remnant prairies in 1995 (Tables 1, 2, and 3). The Ohio Biological Survey manages the portion of the grant pertaining to Lepidoptera. Inventories in Ohio's remnant prairies continued through 30 June 1997.

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SMOOTH SUMAC CONTROL WITH PRESCRIBED BURNING AND HERBICIDES

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ABSTRACT: Smooth sumac (*Rhus glabra* L.) is a deciduous shrub that can spread quickly by a network of lateral roots to form dense thickets. In Nebraska, dense canopies of the thickets alter the microclimate commonly resulting in shifts in the native plant community from warm-season grass dominants to less desirable cool-season species. The objective of this study was to determine if stem density of smooth sumac could be reduced by prescribed burning in conjunction with herbicide treatment or by herbicides alone. The research was replicated in 1994 and 1995 in north-central Nebraska. Prescribed burns were conducted in late May, and the herbicides (2,4-D, 2,4-D + dicamba, and picloram) were applied one month later. Stem density following burning and herbicide applications was analyzed as a split plot design with the pretreatment stem density as a covariate. Prescribed burning increased stem density of smooth sumac, altered the age structure of the clone, and increased warm-season grasses. Stem densities were reduced by the three herbicides to less than 1 stem/m2, regardless of burning before application. If the management goal is to reduce smooth sumac stem density and to stimulate warm-season grasses, a combination of prescribed burning and herbicide treatment should be considered.

Key words: prescribed burning, herbicides, stem density, smooth sumac, *Rhus glabra*

INTRODUCTION

Smooth sumac (*Rhus glabra* L.) occurs from Canada to Mexico and is the only woody species native to all 48 contiguous states. It can quickly invade heavily grazed areas (Lovell 1964). Unlike most woody species, the stem density and vigor of smooth sumac populations may increase following spring fires (Aldous 1934, Lovell 1964, Anderson et al. 1970, Wright 1972, Owensby and Smith 1973, Launchbaugh and Owensby 1978, Adams et al. 1982, Evans 1983, Knapp 1984). The understory of dense stands of smooth sumac commonly lacks diversity, is low yielding, and is dominated by cool-season species such as Kentucky bluegrass (*Poa pratensis* L.). Smooth sumac clones also may facilitate the invasion of trees into rangeland and abandoned fields in the absence of fire by causing alterations in the microclimate that favor xerophytic trees such as bur oak (*Quercus macrocarpa* Michx.) and other hardwood trees (Weaver 1919, Kucera 1960). Management of smooth sumac is a concern of landowners and managers wanting to optimize forage production and maintain diverse grasslands.

Prescribed burns may be successful in reducing stem density when they are conducted at the time smooth sumac has low carbohydrate reserves, such as in early June when flower buds appear (Aldous 1930, 1934). Smooth sumac reserves, however, are depleted and stored at the same time as warm-season perennial grass dominants; therefore, prescribed burns timed to favor warm-season grasses will probably favor smooth sumac (Owensby and Smith 1973). Thus, late-spring fires conducted to improve warm-season grass production also will increase the density and vigor of smooth sumac thickets.

Several herbicides are known to effectively control smooth sumac. Churchill et al. (1976) reported complete control of smooth sumac when using 2,4-D (2,4-dichlorophenoxy acetic acid), 2,4,5-T [2,4,5-(trichlorophenoxy)acetic acid], and picloram (4-amino-3,5,6-trichloropicolinic acid, potassium salt) at rates of 1.12 kg ha-1 applied during the first two weeks of June. This application date coincides with the time when a maximum gradient exists between carbohydrate levels in leaves and roots (Churchill et al. 1976).

There is insufficient information on the influence of spring prescribed burning and herbicide application timed with flowering for the control of smooth sumac. The objective of this study was to determine the effect of prescribed burning and herbicides, alone and in combination, on 1) stem density of smooth sumac clones and 2) above-ground plant production.

METHODS

This study was conducted in 1994 and 1995 on native rangeland near Stuart, Nebraska (42° 48' 46.1" N; 99° 12' 47.3" W), on north-facing slopes of the Niobrara River valley. Soils at the research sites are an association of Labu silty clay (Vertic Ustochrepts) and Sansarc silty clay (Typic Ustorthents). Mean annual precipitation is 551 mm, with 440 mm falling in the April-through-September growing season. The pasture in which the study was conducted had not been grazed since 1988 and had not been burned for at least 30 years. Livestock continued to be excluded from the study sites in 1994 and 1995. Two separate smooth sumac clones which appeared to have uniform height and no dead stems were selected in each year.

The experiment was designed as a randomized-complete-block arranged as a split-plot with a 2-x-4 factorial arrangement of subplot treatments and three replications per treatment combination. Two whole plots (24 x 22 m) in each block were either not burned or burned with a headfire on May 19, 1994 and May 23, 1995 after smooth sumac leaf appearance. Burns were conducted in the late afternoon, and the prefire conditions were recorded immediately prior to burning. Weather conditions for both years were within recommended burning prescriptions for Nebraska (Masters and Stubbendieck 1988).

Estimates of fine-fuel loads were determined for all plots to be burned by clipping the vegetation at ground level immediately before the prescribed burn each year. Three randomly located quadrats (0.1 m^2) were clipped in each of the four subplots of the three designated burn whole plots. The vegetation was dried in a forced-air oven at 65°C until reaching a constant weight. Estimated fine-fuel loads were above the recommended 1100 kg ha^{-1} (Masters and Stubbendieck 1988), and the fuel was uniformly distributed. Mean fine-fuel loads were greater in 1994 than in 1995 (P=0.0001), 4592 and 3108 kg ha^{-1}, respectively.

Herbicides were applied to the subplots (6 x 10 m) on June 17, 1994 and June 21, 1995 when the unburned smooth sumac was flowering and after foliage developed on burned smooth sumac. The herbicides used were 1) picloram, 2) 2,4-D LV4 ester, and 3) 2,4-D LV4 ester + dicamba (3,6-dichloro-o-anisic acid). Each herbicide treatment was randomly applied to one of the four subplots within each whole plot of all three blocks. One subplot within each whole plot was not treated with an herbicide. Picloram at 0.57 kg ha^{-1} , 2,4-D ester at 2.2 kg ha^{-1}, or 2,4-D ester + dicamba at 0.57 kg ha^{-1} and 0.57 kg ha^{-1} were applied to the foliage. Water was used as the carrier for all herbicides and applied at 50 l ha^{-1}. The herbicides were applied by a hand held boom attached to a CO2 pressurized backpack sprayer set at 220 kPa.

Sampling was confined to within transects (2 x 8 m) located in the center of each subplot to reduce influence of drift of the herbicides across plot borders. Sampling data consisted of stem density and yield of above-ground biomass. All stems within the transects were counted before the prescribed burn for an estimate of the initial stem density. Plots were recounted in June, about one month after the burn. Only stems with live foliage were counted. The June counts served as the preherbicide and post-fire treatment estimates of stem density. All plots were counted again in August, about seven weeks after treatment with herbicides. Defoliated stems were not counted. A final count was made one year later on May 22, 1995 for only the plots treated in 1994.

Vegetation biomass was sampled in the first week of August to estimate total above-ground plant production. Five 0.5-m^2 quadrats were clipped within the sampling transect of each subplot. Clipped vegetation was divided into five groups: warm-season grasses, cool-season grasses, forbs, smooth sumac, and other shrubs. Only the current year's growth was sampled, including only new stem growth and leaves of the shrubs. Samples were dried at 65°C until a constant weight was reached to provide estimates of biomass yield.

Stem density data were analyzed with the SAS general linear models procedure (SAS 1990). All comparisons were made at an alpha level of 0.05. Stem densities prior to the prescribed burn for both years were analyzed as a completely randomized design to determine if significant differences existed among the subplots, whole plots, and blocks within each year. Mean prefire stem densities for both years also were analyzed for differences. Mean differences in stem densities measured before and one month after the prescribed burn were analyzed as a randomized complete block design to estimate the fire effect alone. An analysis of covariance for a split plot with randomized complete block design was used to estimate the fire and herbicide effect (Miles-McDermott et al. 1988). Analysis was performed on stem density data collected seven weeks after herbicide treatment. Data used as the covariance factor were the prefire stem densities. Data from each year were analyzed separately if a year effect was detected. Fisher's protected LSD test and preplanned single degree of freedom contrasts were used to delineate differences in stem density among herbicides.

Biomass data were analyzed by vegetation type as a split plot design with randomized complete blocks. An analysis of variance was conducted on the data from each year separately. Fisher's protected LSD was applied to significant model effects to determine differences in biomass among herbicides for each vegetation type. Data were transformed by 1+log when there was a dependence between the fire or herbicide effects and the block effects.

RESULTS

June through August precipitation was 139 mm above the long-term average in 1994, and it was 90 mm below average for the same period in 1995. These precipitation differences caused the year effect to be always significant (P<0.05); therefore, results are presented by year. Live stem densities of smooth sumac one month following prescribed burning were greater on the burned whole plots than on the unburned whole plots in both years (Figures 1 and 2). Live stem densities of smooth sumac were similar on the whole plots immediately prior to burning. A greater increase ($P < 0.05$) in mean stem density on burned plots occurred in 1994 (3.0 stems m^{-2}) than in 1995 (2.4 stems m^{-2}). The lower number of new stems in 1995 may be attributed to a precipitation deficit

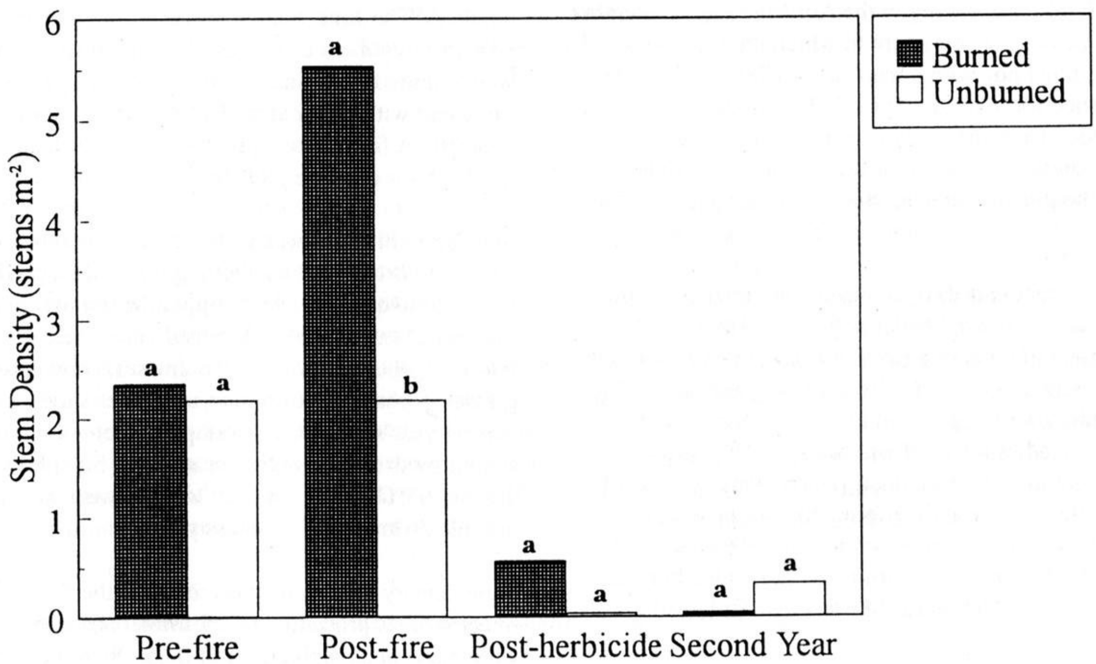

Figure 1. Mean stem densities of herbicide treated plots in 1994, excluding the control plots. Stem densities were measured before the prescribed burn, 1 month after burning, 7 weeks after herbicide treatment, and 1 year after burning.

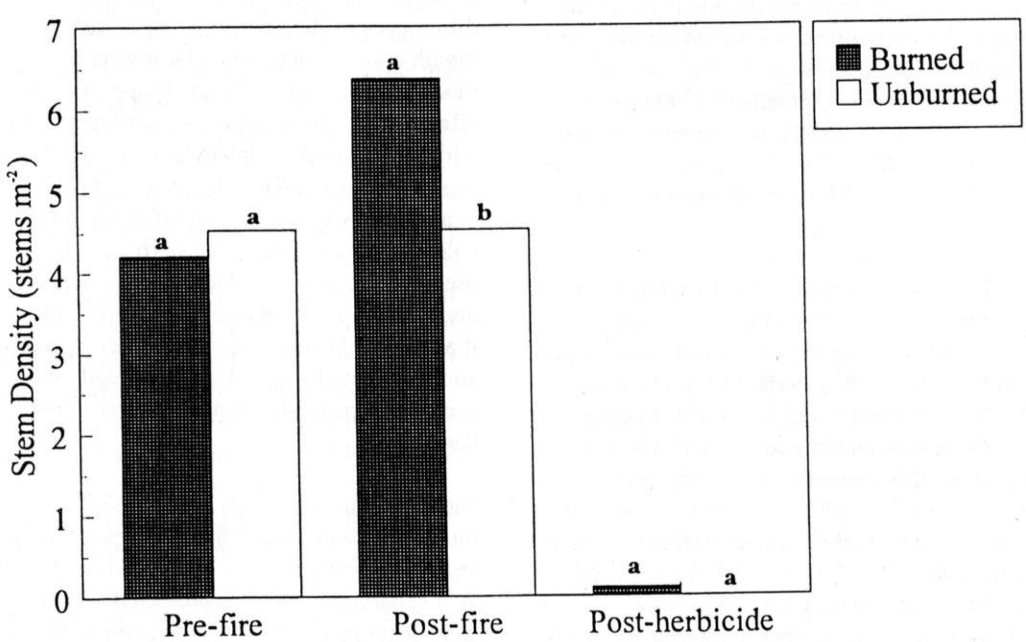

Figure 2. Mean stem densities of herbicide treated plots in 1995, excluding the control plots. Stem densities were measured before the prescribed burn, 1 month after burning, and 7 weeks after herbicide treatment.

in June that was 77 mm below the long-term average (National Climate Center 1995).

Smooth sumac stem density decreased ($P<0.05$) following herbicide application both years (Figures 3 and 4). Live smooth sumac stem density was decreased equally ($P > 0.05$) by 2,4-D ester, 2,4D ester + dicamba, and picloram within each burn whole plot seven weeks following herbicide application. Application of the herbicides at the initiation of flower buds appeared to be highly effective in reducing smooth sumac live stem density. Although there was no difference in herbicide effectiveness between the burned and nonburned treatments, application was easier on burned plots due to the alteration of the age structure of the clone and reduction in stem height. Stem densities of the plots treated with herbicides in 1994 were still similar one year later (Figure 1).

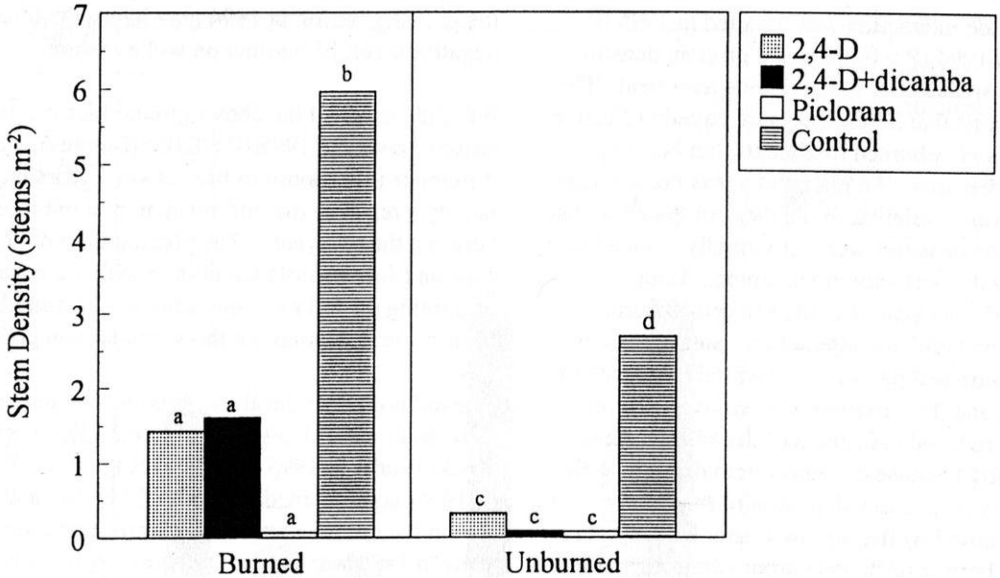

Figure 3. Mean stem densities for herbicide effects in 1994. Stem densities were measured 7 weeks after herbicide treatment. Herbicide treatments with the same letter superscripts are not different at the 0.05 level as determined by Fisher's protected LSD test. Burned and unburned plots were analyzed separately.

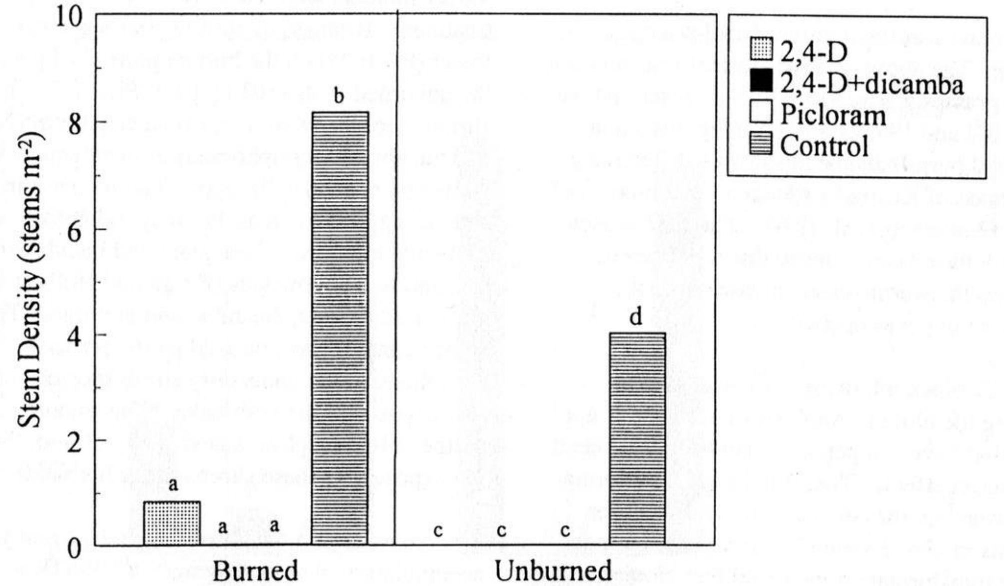

Figure 4. Mean stem densities for herbicide effects in 1995. Stem densities were measured 7 weeks after herbicide treatment. Herbicide treatments with the same letter superscripts are not different at the 0.05 level as determined by Fisher's protected LSD test. Burned and unburned plots were analyzed separately.

Prefire stem densities were used as a covariate to analyze the combined effects of fire and herbicides. A whole plot analysis on the effect of fire in conjunction with herbicide treatment indicated that there was no difference ($P > 0.05$) between burned and unburned stem densities seven weeks following herbicide application in both 1994 and 1995. Despite the increase in post-fire stem density, the herbicides reduced the stem densities similarly on the burned and unburned plots (Figures 3 and 4).

A fire by herbicide interaction was detected in 1995 ($P < 0.05$), but not in 1994 ($P > 0.05$) based on stem densities measured seven weeks after the herbicide treatment. The interaction suggests that herbicides were equally effective on both burned and unburned treatments, but burning increased stem densities. An interaction was not detected in 1994 due to more variation in the data compared to that of 1995, when the densities were all virtually reduced to 0 stems per m^{-2} on the herbicide-treated plots. Data collected in 1995, one year after the prescribed burn, indicated a fire by herbicide interaction. Stem densities on the herbicide-treated plots were essentially reduced to 0 stems per m^{-2}, and the variation was removed. Herbicides may have reduced the fitness of the smooth sumac clones sufficiently to cause collateral stem death over the winter. This may be due to a depletion of the stored carbohydrates caused by the regrowth after burning; thus, there may have been insufficient carbohydrate supply to initiate bud elongation in the following spring. Furthermore, decreases in stem density on the 1994 plots may have been due to increased competition from the native grasses for soil, water, nitrogen, and/or other nutrients, because the grasses were stimulated by the results of the fire and opening of the smooth sumac canopy.

Kentucky bluegrass was the dominant cool-season grass prior to burning. The above-ground, current year biomass of cool-season grasses was reduced by the prescribed burn in 1994 ($P < 0.05$) and 1995 ($P < 0.05$) (Figures 5 and 6). Spring prescribed burns have been shown to effectively reduce the biomass of Kentucky bluegrass and other cool-season grasses (Anderson et al. 1970). The cool-season grasses also may have been reduced due to increased competition with the warm-season grasses once the smooth sumac canopy was opened.

In 1994, a fire by block interaction occurred due to variation among the blocks. Analysis of variance is not valid for data that have a dependence between treatment effects and random effects. Therefore, a log transformation was performed on the data (Dowdy and Weardon 1991). Analysis of above-ground, current year biomass data following transformation indicated that biomass of warm-season grasses was increased by the prescribed burning ($P < 0.05$) (Figure 5). Warm-season grass biomass on the burned plots was 1723 kg ha^{-1} and only 192 kg ha^{-1} on the unburned plots.

Big bluestem was the dominant warm-season grass on the plots treated in 1994, and it responded favorably to burning. The increased productivity of big bluestem may have been related to reduction in the cool-season grasses and canopy, as well as the removal of the accumulated mulch (Rice and Parenti 1978). Typically, the soil moisture in burned areas is lower later in the growing season which allows the unburned prairie production to partially approach the production on burned areas (Knapp 1984). However, the above average precipitation during the growing season in 1994 may have counteracted the negative effect of burning on soil moisture.

Fire did not affect the above-ground biomass of warm-season grasses in 1995 ($P > 0.05$) (Figure 6). The difference in response to fire between years may be largely a result of the difference in precipitation patterns between the two years. The precipitation deficit during June and July in 1995, combined with the negative effects of burning on soil moisture, may have resulted in the lack of increase in biomass of the warm-season grasses.

Fire did not affect the above-ground, current year biomass of forbs in 1994 ($P > 0.05$) (Figure 5), but it affected mean yield of forbs in 1995 ($P < 0.05$) (Figure 6). Forb biomass in 1995 on the burned plots was 27 kg ha^{-1} and only 1 kg ha^{-1} on the unburned plots. The most common forb in the plots in 1995 was western ragweed (Ambrosia psilostachya DC.). The response of the forbs in 1995 is contrary to the reported negative effect of late spring burns on perennial forbs (Anderson et al. 1970).

Fire did not affect shrub above-ground, current year biomass accumulation in 1995 ($P > 0.05$) (Figure 6). Shrub numbers were very low on the 1995 plots prior to treatment. Biomass of current year's growth in 1994 was lower ($P < 0.05$) on the burned plots (17 kg ha^{-1}) than on the unburned plots (503 kg ha^{-1}) (Figure 5). The dominant shrubs were leadplant [Amorpha canescens (Nutt.) Pursh] and buckbrush (Symphoricarpos occidentalis Hook.). Anderson et al. (1970) reported an increase in shrubs on late spring burned areas, but they did not use a follow up herbicide treatment. Leadplant and buckbrush are susceptible to herbicides (Bragg and Hulbert 1976), particularly 2,4-D, dicamba, and picloram. The smooth sumac canopy was removed by the prescribed burn, and the foliage of the understory shrub species in these plots was exposed to the herbicides. The smooth sumac canopy on the unburned plots was virtually closed, thus reducing the exposure of these shrubs to the herbicide.

Fire did not affect the above-ground current year biomass accumulation of smooth sumac in 1995 ($P > 0.05$) (Figure 6). Current year biomass in 1994 was greater ($P < 0.05$) on the unburned plots (1030 kg ha^{-1}) than on the burned plots (100 kg ha^{-1}) (Figure 5). Although there was a significant increase in stem density on the burned plots, the above-ground biomass of the new shoots was much less than that of the mature plants in the unburned control plots.

Herbicides had no effect on the above-ground current year biomass of the cool-season grasses or warm-season grasses in either 1994 or 1995 ($P > 0.05$) (Figures 7 and 8). Above-ground biomass of the forbs was unaffected ($P < 0.05$) by herbicide treatment in 1994 (Figure 7).

Herbicides did affect forb biomass in 1995 ($P < 0.05$). Plots treated with 2,4-D ester and 2,4-D ester + dicamba had lower above-ground biomass estimates than the picloram-treated and control plots (Figure 8).

Current year above-ground biomass of the other shrubs was unaffected by herbicides in 1995 ($P > 0.05$), but was affected in 1994 ($P < 0.05$) (Figures 7 and 8). Plots treated with 2,4-D ester and 2,4-D ester + dicama had

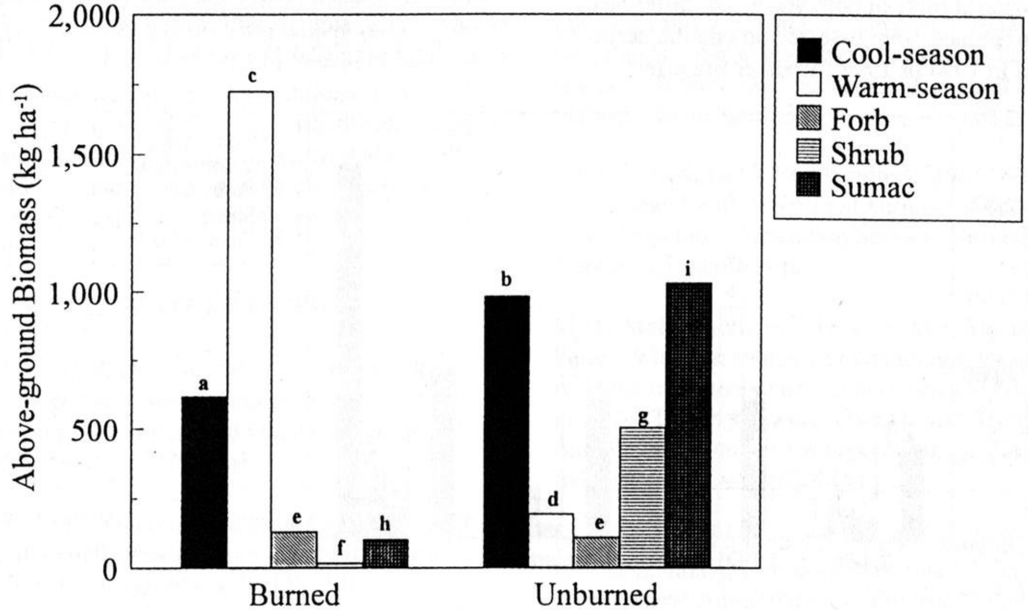

Figure 5. Fire effect on above-ground biomass for 1994. Columns with the same letter superscript are not significantly different at the 0.05 level as determined by Fisher's protected LSD method. Comparisons are made within the vegetation groups.

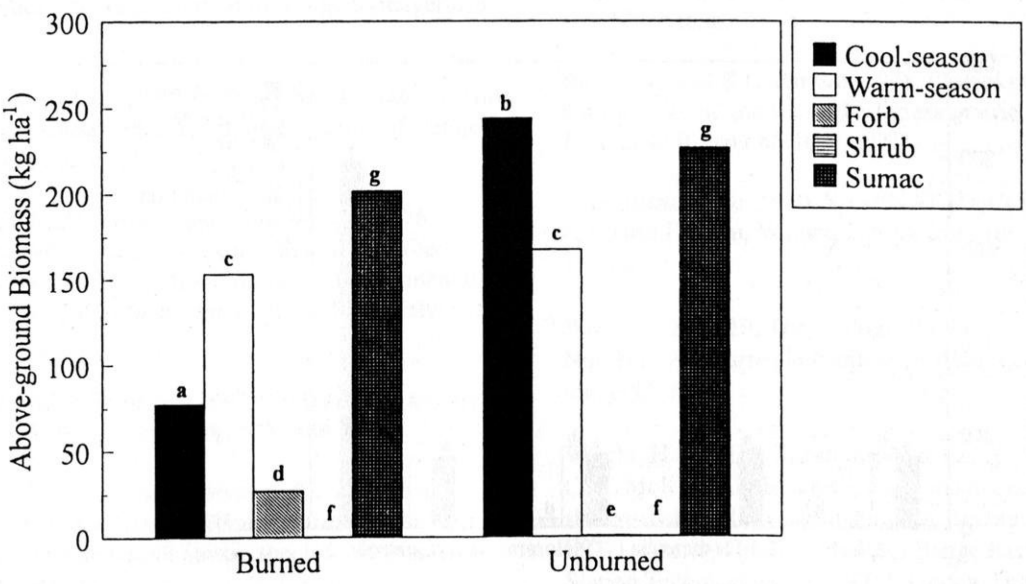

Figure 6. Fire effect on above-ground biomass for 1995. Columns with the same letter superscript are not significantly different at the 0.05 level as determined by Fisher's protected LSD method. Comparisons are made within the vegetation groups.

lower above-ground biomass estimates than the picloram-treated plots (Figure 8). The difference in shrub response to herbicides between years may be due to the smaller shrub mean biomass on the 1995 (0.2 kg ha^{-1}) than on the 1994 (260 kg ha^{-1}) plots.

Biomass of smooth sumac was influenced by the herbicides in both 1994 and 1995 ($P < 0.05$) (Figures 7 and 8). Current year above-ground biomass of smooth sumac on plots treated with the three herbicides was lower ($P < 0.05$) than on control plots in both years. No differences in current year biomass were detected among the herbicide treatments in 1994 or 1995 for either fire effect. These results are consistent with the herbicide effects on stem density.

CONCLUSIONS

Smooth sumac stem density was decreased by herbicide treatment with or without prescribed burning prior to herbicide application. Also, the three herbicides had no effect on the above-ground current year biomass of the cool-season and warm-season grasses and little effect on forbs. The most cost effective method of reducing smooth sumac stem density would be to apply 2,4-D ester without burning (2,4-D ester is \$2.70 ha^{-1}; 2,4-D ester +

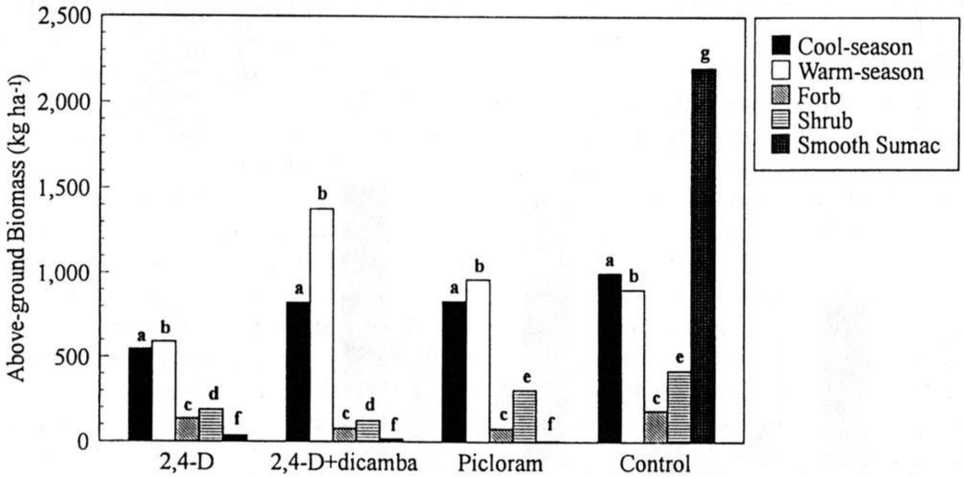

Figure 7. Herbicide effect on above-ground current year biomass for cool-season grasses, warm-season grasses, forbs, shrubs, and smooth sumac in 1994. Columns with the same superscripts are not significantly different at the 0.05 level as determined by Fisher's protected LSD test. Comparisons are made within the vegetation groups.

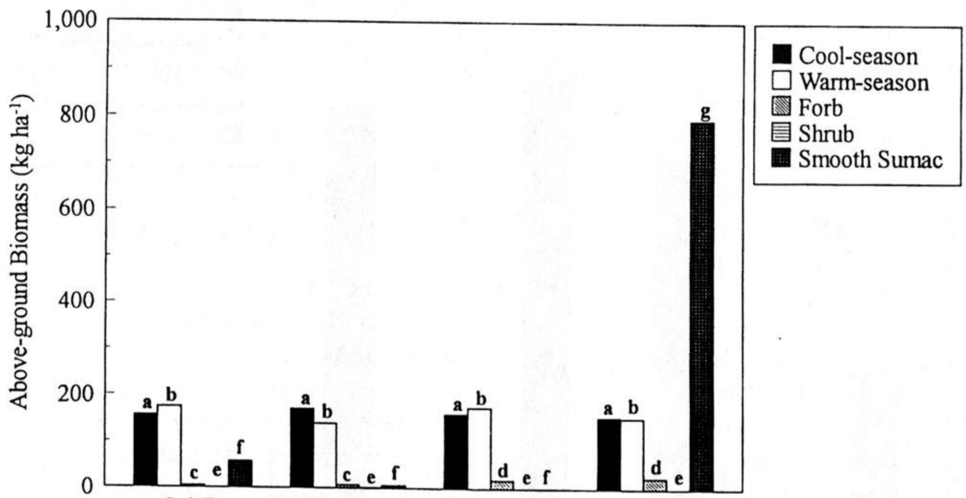

Figure 8. Herbicide effect on above-ground current year biomass for cool-season grasses, warm-season grasses, forbs, shrubs, and smooth sumac in 1995. Columns with the same superscripts are not significantly different at the 0.05 level as determined by Fisher's protected LSD test. Comparisons are made within the vegetation groups.

dicamba is \$5.00 ha^{-1}; picloram is \$11.52 ha^{-1}). Application of herbicides at initiation of flower buds appears to be highly effective in reducing the stem density of smooth sumac. Stem density of smooth sumac on unburned plots treated with 2,4-D ester was essentially reduced to 0 in both years.

If the management goal is to reduce smooth sumac stem density and stimulate warm- season grasses, a combination of prescribed burning and herbicide treatment should be considered. A late spring prescribed burn would be most effective in increasing warm-season grass production, and 2,4-D ester would be the most cost effective of the three herbicide treatments. An additional benefit of burning before applying herbicides is that the stem height of smooth sumac is greatly reduced which makes herbicide application easier. Burning also removes the smooth sumac canopy and exposes other unwanted shrub species to the herbicide.

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BEE VISITORS OF FOUR RECONSTRUCTED TALLGRASS PRAIRIES IN NORTHEASTERN ILLINOIS

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ABSTRACT: Bees visiting four reconstructed tallgrass prairie plots were inventoried to investigate if a remnant assemblage of bees native to tallgrass prairie has persisted in the local area. All sites were located on the campus of the College of DuPage, Illinois. The inventory reflected a fauna of bees that are widely distributed throughout the U.S. Bumble bees (Bombus *spp.)* and sweat bees *(Halictus spp.)* were most abundant. The absence of *B. fraternus,* which was more common within prairie of Northeastern Illinois 60 years ago, and the current relative rarity of bees like the sweat bees *Augochlorella striata* and *H. ligatus,* indicate the effect anthropogenic disturbances have had on the bees visiting the prairie plots. Widespread distributions of the bees inventoried confound determination of whether a remnant assemblage of bees characteristic of tallgrass prairie has persisted.

Key words: bees, tallgrass prairie reconstruction, inventory, anthropogenic disturbance.

INTRODUCTION

Tallgrass prairie reconstruction attempts to preserve native biodiversity in a state where only 0.01% of quality remnants remain (IDENR 1994, Samson and Knoph 1994). Prior to 1820, an estimated 8,900,000 ha of tallgrass prairie covered the northern two-thirds of Illinois. Within 60 years, much of the prairie was converted to farmland because of land incentives from the federal government and the Illinois Central Railroad (Burt 1969, Hayes 1927, IDENR 1994, Smith 1990). In DuPage County, where the current study was located, only 8 ha remain from the original 74,800 ha (IDENR 1994). The county occupies an area of 97,400 ha. Floral restoration has been largely the focus of reconstruction efforts (Schramm 1990), with relatively little emphasis given to native consumers. This bias is understandable as flora visually characterize the tallgrass prairie. However, native consumers, as regulators of energy flow and nutrient cycling, may be essential to successful persistence of a restored plot through time. The hope that a sufficient number of native consumers, such as insects, have somehow persisted and will be able to colonize reconstructed sites from the anthropogenically changed landscape may not be well founded, although non-native consumers may offer functional replacements.

In this study, bees (Hymenoptera) colonizing four reconstructed, tallgrass prairie plots on the campus of the College of DuPage were surveyed. The objective was to investigate if a remnant assemblage of bees native to tallgrass prairie has persisted in the local area. Bees were chosen as indicators of essential fauna colonization because of their importance as pollinators (Dickinson and McKone 1992) and for those that nest in the soil, as soil mixers and aerators.

METHODS

Study Sites

College of DuPage is located within the heart of residential DuPage County, which contributes to the metropolitan area of Chicago. Sizes and dates of initial reconstruction of the four tallgrass plots are provided in Table 1. The plots, which are located within 250 m of one another, were created by Russell Kirt and students of the college. Prior to college acquisition in 1965, the land was farmed. Except for the Southeast Prairie (SEP), clay removed from campus construction projects provided the subsoil, and black soil composed the upper 8 cm of earth in the plots. The SEP was reconstructed on the existing soil found prior to college purchase. The tallgrass prairie plots contain some 150 floral species which have been established after seed broadcasting and seedling transplant. Big bluestem *(Andropogon gerardii* Vitman), Indian grass *(Sorghastrum nutans* (L)) and prairie dropseed *(Sporobolus heterolepsis* Gray) are the predominant grasses. Three species of wild indigo *(Baptisia* Vent.), compass plant *(Silphium laciniatum L.),* and several species of aster (*Aster*) and goldenrod (*Solidago*) are among the decorative species of the prairie plots. Burning of the four plots is done annually, usually during fall or early spring.

Procedures

From April to October in 1993 and 1995, bees were collected bimonthly using sweep net and jar collections along two randomly selected transects per site between the hours of 9 a.m. and 3 p.m. Central Daylight Time (CDT). The order of sites sampled was varied during each

Table 1. The sizes and dates of initial reconstruction of the four tallgrass plots located on the main campus of College of DuPage, Illinois.

Tallgrass plot	Size (hectares)	Date of initial reconstruction
East Prairie	0.6	1975
Southeast Prairie	0.8	1992
West Prairie	0.8	1986
Southwest Prairie	1.8	1990

collecting period. The flowering plants where collections were taken were also recorded. It was assumed, based on the rigors in which the bees penetrated flowers, that pollination was possible. However, pollen collection and distribution were not measured. Taxonomic keys of Mitchell (1960,1962) were used to identify bees. Voucher specimens have been retained at College of DuPage. Arnett (1985), Evans (1986), Hendrickson (1929), Mitchell (1960,1962), and Pearson (1933) provided valuable fauna information of distribution including records from Northeastern Illinois during the first half of the century.

RESULTS AND DISCUSSION

Table 2 provides the list of bees identified from the restored prairie plots, as well as notes on distribution and floral specialization. Tables 3 and 4 summarize bee visitors according to plant species and the phenology of bees visiting flowers, respectively. Floral specialization was determined by the number of visitations of taxonomically diverse plant species as recorded in the literature. Insufficient information was found concerning the distribution and floral specialization by the digger bee, *Exomalopsis asteris.* All of the remaining bees are known to be widely distributed and generalists (or polyleges). Except for bumblebees (*Bombus* spp.) and the sweat bee (*H. confusus*) most bees were rarely encountered, including the globally distributed honeybee (*Apis mellifera*). Rarity was thought to be the major factor having influenced abundance, although sampling time, avoidance of capture, and possibly the lack of attraction to the prairie plots offer alternative explanations.

The digger bee (*Melissodes agilis*), all of the apids, yellow-faced bees, and sweat bees identified also were observed by Pearson (1933) in an earlier survey of bees of northeastern Illinois. The sweat bees (*Augachlorella striata* and *H. ligatus*) were found to be particularly numerous and widespread. Pearson even labelled *H. ligatus* a prairie bee, because despite a general distribution, it was predominately found visiting prairie. A noticeable bee missing from the current inventory was the bumblebee, *Bombus fraternus* (Smith), another "prairie bee" identified by Pearson. While some bees characteristic of (but not necessarily unique to) tallgrass prairie may have persisted, they likely have done so because of tolerance to habitat variability, including variability caused by human alteration. Widespread distributions confound determination of whether a remnant assemblage of bees characteristic of tallgrass prairie has persisted, especially where fauna records prior to 1820 are lacking.

The absence of *B. fraternus* and, perhaps, the relative rarity of bees like the sweat bees, *A. striata* and *H. ligatus*, indicate the effect anthropogenic disturbance has had on the local bee population. It remains unknown how this has affected reconstruction efforts of the floral community as other bee species, such as *B. bimaculatus* and *B. fervidus,* may have offered functional replacements. Prolific flowering in species such as the white wild indigo (*Baptisia leucantha*) (Petersen and Sleboda 1994), has been associated with competition for pollinators. Discriminating pollinators may favor certain plants over others and thus affect prairie plot succession. Future investigations may examine the importance of pollinator bias to floral succession in and thus the management of restored plots.

CONCLUSIONS

The bees inventoried in the restored tallgrass plots reflected a fauna widely distributed throughout the U.S. Bumblebees (Bombus spp.) and sweat bees (*Halictus* spp.) were most abundant. The absence of *B. fraternus*, which was more common within prairie of northeastern Illinois 60 years ago, and the current relative rarity of bees like the sweat bees, *Augochlorella striata* and *H. ligatus*, indicate the effect anthropogenic disturbance has had on the bees visiting the plots.

Table 2. Listing of bee species collected from the four restored prairie plots as indicated by the abundance (1993 and 1995 data) of individuals recorded. Also provided is distribution within the United States and degree of floral specialization. Symbols: EP=East Prairie, SEP=Southeast Prairie, WP=West Prairie; and SWP=Southwest Prairie. References for categorizing floral specialization: [1] Arnett (1985); [2] Evans (1986), [3] Hendrickson (1929); [4] Mitchell (1960); [5] Mitchell (1962), and [6] Pearson (1933).

Species	Study Site				Distribution and floral specialization
	EP	SEP	WP	SWP	[Source]
Family Anthophoridae (Cuckoo Bee, Digger Bee and Carpenter Bee Family)					
Exomalopsis asteris Alex	10-0	4-0			
Melissodes agilis Cresson	1-0		0-1		Throughout the United States, generalist [5]
Xylocopa virginica (Linnaeus)				0-1	Eastern half of the United States, generalist [5]
Family Apidae (Bumble Bee and Honey Bee Family)					
Apis mellifera Linnaeus	0-8	0-1	1-1	1-1	Worldwide [1-5], generalist [1,5,6]
Bombus bimaculatus Cresson	43-25	11-31	24-4	1-0	Eastern half of the United States [1], generalist [2,5]
Bombus fervidus Fabricius	26-23	24-29	16-14	0-1	Throughout the United States, generalist[3,5]
Bombus pennsylvanicus (DeGeer) 3-1	1-0	1-1			Throughout the United States, generalist [3,5]
Bombus vagans Smith	0-20	0-1	0-1		Eastern half of the United States, generalist [5]
Family Colletidae (Yellow-faced and Plasterer Bee Family)					
Hylaeus illinoensis Robertson			0-1		Northeastern United States, generalist [4]
Family Halictidae (Sweat Bee Family)					
Auguchlorella striata (Provancher) 0-1					Eastern half of the United States, generalist [4]
Dialictus anomalus(Robertson)	1-1	2-1	0-1		Eastern half of the United States, generalist [4,6]

Continued on next page

Table 2. continued.

Species	Study Site				Distribution and floral specialization
	EP	SEP	WP	SWP	[Source]
Halictus confusus Smith	2-27		6-3		East of the Rocky Mountains[4], generalist[2,4]
Halictus ligatus Say	4-1	1-0			Throughout the United States [4], generalist [2,4,6]
Halictus rubicundus (Christ)	2-1	2-9	6-1	0-2	Holarctic and Nearctic [4], generalist [2,4]
Family Megachilidae (Leaf-cutting and Mason Bee Family)					
Megachile melanophoea Smith			1-0	0-1	Throughout the United States, generalist [5]

Table 3. Bee visitors according to plant species. An asterisk denotes an introduced plant species as specified by Swink and Wilhelm (1994).

Plant species	Bee visitor(s)
Family Apiaceae	
Zizia aurea (L.) W D.J. Koch (Golden Alexanders)	*Exomalopsis asteris*
Family Asclepiadaceae	
Asclepias tuberosa L. (Butterfly Milkweed)	*Melissodes agilis*
Family Compositae	
**Arctium minus* Schkuhr (Common Burdock)	*Bombus fervidus, Halictus rubicundus*
Aster dumosus L. (Bushy Aster)	*Apis mellifera, Bombus bimaculatus*
Aster ericoides L. (Heath Aster)	*Apis mellifera*
Aster laevis L. (Smooth Blue Aster)	*Apis mellifera, Bombus bimaculatus*
Coreopsis tripteris L. (Tall Coreopsis)	*Bombus bimaculatus, Bombus fervidus, Halictus rubicundus, Megachile melanophorea*

Continued on next page.

Table 3. continued.

Plant species	Bee visitor(s)
Erigeron philadelphicus L. (Marsh Fleabane)	*Exomalopsis asteris, Bombus fervidus, Dialictus anomalis, Dufourea marginata, Halictus ligatus*
Rudbeckia hirta L. (Black-eyed Susan)	*Bombus bimaculatus, Halictus rubicundus*
Silphium laciniatum L. (Compass Plant)	*Bombus bimaculatus, Bombus fervidus, Bombus vagans*
Silphium terebinthinaceum Jacq. (Prairie Dock)	*Melissodes agilis, Bombus imaculatus, Halictus rubicundus*
Solidago altissima L. (Tall Goldenrod)	*Apis melifera, Bombus fervidus*
Solidago rigida L. (Stiff Goldenrod)	*Bombus bimaculatus*
**Taraxacum officinale* Webber (Dandelion)	*Exomalopsis asteris, Dialictus anomalis*
Family Euphobiaceae	
Euphorbia corollata L. (Flowering Spurge)	*Bombus fervidus, Halictus rubicundus*
Family Lamiaceae	
Monarda fistulosa L. (Wild Bergamot)	*Bombus bimaculatus, Bombus fervidus, Bombus pennsylvanicus, Bombus vagans, Halictus confusus*
Family Leguminosae	
Amorpha canescens Pursh (Lead Plant)	*Bombus bimaculatus. Bombus fervidus*
**Baptisia australis* (L.)R. Br. (Blue Wild Indigo)	*Halictus ligatus*
Baptisia leucantha T&G (White Wild Indigo)	*Bombus bimaculatus, Bombus fervidus, Bombus pennsylvanicus*
Baptisia leucophaea Nutt. (Cream Wild Indigo)	*Bombus fervidus, Bombus pennsylvanicus*
Quercus macrocarpa Michx. (Bur Oak)	*Halictus rubicundus*
**Melilotus alba* Medik. (White Sweet Clover)	*Dialictus anomalis*
**Melilotus officinalis* (L.) Pall. (Yellow Sweet Clover)	*Xylocopa virginica, Apis mellifera*
Petalostemum candidum (Willd.) Michx. Clover)	*Bombus bimaculatus, Bombus fervidus,* (White Prairie *Halictus rubicundus*
Petalostemum purpureum . (Vent.) Rydb. (Purple Prairie Clover)	*Bombus fervidus, Halictus rubicundus*

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Table 3. continued.

Plant species	Bee visitor(s)
**Trifolium pratense* L. (Red Clover)	*Apis mellifera, Halictus confusus*
Family Rosaceae	
Spiraea alba Du Roi (Meadowsweet)	*Apis mellifera*
Family Scrophulariaceae	
Penstemon pallidus Small (Pale Beard Tongue)	*Halictus rubicundus*
Veronicastrum virginicum (L.) Farw.	*Bombus fervidus, Bombus vagans,* (Culvers Root) *Augachlorella striata, Halictus confusus, Halictus ligatus*
Family Umbelliferae	
**Daucus carota* L. (Queen Annes Lace) *Hylaeus illinoensis, Dialictus anomalis,*	*Bombus bimaculatus, Bombus fervidus, Halictus confusus, Halictus rubicundus*

Table 4. Phenology of bees visiting flowers

Species	Month May	June	July	August	Sept.	October
Exomalopsis asteris	XXXXXXXXX					
Melissodes agilis			X	X		
Xylocopa virginica		X				
Apis mellifera		XXXXXXXXXXXXXXXXXXXXXX				
Bombus bimaculatus		XXXXXXXXXXXXXXXXXXXXXXX				
Bombus fervidus	XXXXXXXXXXXXXXXXXXXXXXX					
Bombus pennsylvanicus	XXXXXXXXXXXXXXXX					
Bombus vagans			XXXXX			
Hylaeus illinoensis				X		
Aucuchlorella striata				X		
Dialictus anomalus	XX		X	X		
Halictus confusus	XXXXXXXXXXXXXXXXXX					
Halictus ligatus	XXXXXXXXX			X		
Halictus rubicundus		XXXX		X		
Megachile melanophoea			X	X		

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Table 2. Listing of bee species collected from the four

THE WESTERN REGION FIRE MONITORING PROGRAM: LONG-TERM MONITORING IN FIRE-MAINTAINED ECOSYSTEMS

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ABSTRACT: The former Western Region of the U.S. National Park Service developed the Fire Monitoring Handbook, which contains a standardized protocol for monitoring and documenting prescribed fire behavior and effects. Four levels of monitoring included in it range from reconnaissance to long-term change. The handbook provides a system to document burning conditions and fire behavior, ensure fires remain within certain conditions, verify completion of burn objectives, and follow long-term trends. This information can help managers refine burn prescriptions when objectives are not met or long-term undesirable trends occur, and identify research needs. In support of the implementation of the handbook, data forms, software, and training courses have been developed. As the program begins its seventh year, a majority of parks with fire management programs have installed the preburn plots necessary to collect fire monitoring data. Five-year post-burn data from sagebrush shrubland at Lava Beds National Monument enable us to monitor the response of perennial bunchgrasses and exotic annual grasses to prescribed fire in the monument. Five-year post-burn data from Giant Sequoia/mixed conifer forest of Sequoia and Kings Canyon National Parks allow us to track the response of trees to prescribed fire in the parks.

Key words: prescribed fire, fire ecology, fire monitoring, long-term monitoring, long-term fire monitoring, fire effects, sagebrush, *Artemesia tridentata*, bunchgrasses, Giant Sequoia, *Sequoiadendron giganteum*, mixed-conifer forest.

INTRODUCTION

A Prescribed and Natural Fire Monitoring Task Force developed the Fire Monitoring Handbook in 1989. This task force consisted of resource management specialists and park scientists involved in fire management. In 1989, the Western Region (expanded since reorganization and now called the Pacific West Field Area) of the U.S. National Park Service published the first edition of the handbook (USNPS 1989) and established several pilot programs. In 1990, all parks in the region with a prescribed fire program were required to have a fire monitoring program. With field participation, the handbook has been subsequently revised and updated (USNPS 1991a, 1992) and was scheduled for another revision in the winter of 1997.

The objectives of the program are to: 1) record basic information for all fires; 2) document immediate post-fire effects of prescribed burns; 3) assist fire managers in assessing and refining prescribed burn programs; 4) share information between land managers; 5) follow trends in plant communities where fire research has been conducted; and 6) identify future research needs.

Program Structure

The handbook defines levels of monitoring activity that are related to fire management goals and strategies. At each successive level, monitoring is more extensive and complex. Level 1 covers reporting of all fires. Levels 2, 3, and 4 call for monitoring of fire conditions, short-term effects, and long-term change, respectively. The levels are cumulative; requirements include all levels below the highest specified. Monitoring at all four levels is required for prescribed burns. The handbook describes monitoring procedures and required frequencies for each level.

Level 1 monitoring provides a basic overview of the fire event, and is essential to all types of fire. Level 2 is used to provide data on ambient conditions and fire and smoke characteristics. These data are coupled with information gathered during Level 1 to predict fire behavior and to identify potential problems.

Level 3 requires collecting information on fuel reduction and/or vegetative change within one to five years after a fire. This permits a quantitative evaluation of whether a stated objective was achieved, such as reducing dead and downed fuels by 60%; or reducing understory density by 50%; or removing 95% of invading shrubs from a grassland.

Level 4 requires collecting information on trends, or change over time, in a managed ecosystem. Once an unexpected trend is detected, a research program and/or an appropriate management response can be established, if necessary. An example of where this type of monitoring would have helped is in the effects of the U.S. National Park Service's total fire suppression policy until 1968. Unknown and undesired effects were not formally recognized for 90 years and only after considerable and often irreversible damage had been done. If a systematic process of monitoring and evaluation had been present during this time, many fire management policies, including full suppression may have been affected. Current fire management strategies also have potential to cause undesired change. Consequently, long-term change monitoring should be strongly considered for all types of fire management strategies, including fire suppression.

Three types of plots or transects are used. The variables for each type of plot are cumulative from grassland to forest plots. Grassland transects monitor the following variables: frequency, relative cover, and burn severity. Brush plots include the above plus: brush density by species and by age. Forest plots include the above plus: tree density, tree diameter, dead and downed fuels, scorch height, and crown scorch. Although these variables are the minimum required, many parks have chosen to monitor additional variables.

Three training courses have been created in association with this program. Classes exist to train plot monitors, burn monitors, and to help managers set up and manage a program.

Monitoring Schedule

Phenological stage during recurrent sampling is as important as the frequency of sampling. Sampling is scheduled to minimize seasonal variation between visits. Plots are revisited when ephemeral species are in a phenological state similar to that of the initial survey, not necessarily at the same date as the initial survey. Some early or late season species can be overlooked using this schedule. If those species are of concern, multiple-season sampling is initiated.

Index plot data are monitored at least two years prior to burning, and preferably one year before burning. Since many plots are not burned within the first or second year of installation, subsequent preburn monitoring visits are conducted.

Fire behavior and weather are monitored and recorded during the burn. Nonherbaceous variables are read within two months after the burn. Vegetation parameters are monitored during the growing season at postburn intervals of one, two, five, and ten years. Thereafter, monitoring occurs at ten-year intervals until each area is either placed within a prescribed natural fire zone or the area is burned again, in which event, the monitoring cycle starts over.

Custom Software

Data is encoded into IBM-compatible personal computers using the Fire Monitoring Handbook software, FMH.EXE. The data entry and analysis program uses dBASE format database files, but is a stand-alone package that does not require any other software to run other than DOS. We are currently refining a Windows-compatible updated version, which contains error checking mechanisms for both data entry and data collection. The software program is available on a single 360K diskette. A software manual (USNPS 1991b) is available as a companion document to the handbook.

Data entry is designed to mimic standard data sheets. The addition of pull-down menus, specific help, and extensive error checking makes FMH.EXE powerful and easy for computer novices to use. Any software that can access dBASE files, i.e., dBASE and FoxBASE, can be used to edit, enter, and analyze the data. However, using FMH.EXE enhances data integrity by providing validated data entry and automated data analyses.

Once data are entered, analysis routines calculate all the minimum variables and some additional variables. Minimum plot calculations and data analyses output the mean and standard deviation and are presented in graphical tabular outputs. Copies of all databases are stored at the Western Regional Office.

Other U.S. National Parks and Agencies

Fourteen parks outside the Pacific West Field Area have established fire monitoring programs based on the Fire Monitoring Handbook. Several others have expressed interest and are seeking funding.

Monitoring programs based on the Fire Monitoring Handbook have been established in: several Fish and Wildlife refuges in Iowa, Minnesota, New Jersey, Texas, Wisconsin, and Florida; US Forest Service areas in California, Illinois, Michigan, Minnesota, Vermont, and Washington; Texas State parks; several California State parks; and Departments of Natural Resources in Minnesota and Missouri. The Bureau of Indian Affairs supports a growing program and provides training support for all fire monitoring training courses.

Program Status

Initially, every park with a monitoring program had a team of technicians to perform all programmatic functions. Now, the workload for this program is divided among six regional teams. Three are mobile, moving between small and medium sized parks. The others are stationed at the three largest parks in the region.

The number of plots installed has decreased every year. These numbers are directly correlated to the shrinking work load, as plot networks are completed. The number of plots that have been reread for postburn monitoring or to update plots has increased as the total number of plots installed has decreased. Future work loads depend directly upon the amount of acreage burned.

The program is supervised by a Program Manager, who works out of the Pacific-Great Basin System Support Office in San Francisco. The increase in participation by parks outside of the Pacific West Field Area has led to the creation of a second Program Manager position located at the Colorado Plateau System Support Office in Denver.

LAVA BEDS NATYIONAL MONUMENT

The fire monitoring program was established at Lava Beds National Monument (NM) in 1989 when the monument was chosen as a pilot park. Research to evaluate the effects of fire on vegetation of Lava Beds NM began in 1974. Much of that information was used to develop and modify handbook guidelines and methods. Human influence in the form of fire suppression, intensive livestock grazing, and the introduction of exotic plant species have changed the composition of brush and grass vegetation types at Lava Beds. The monument's prescribed burn objectives in sagebrush shrubland were to increase the cover of native perennial bunchgrasses and to stabilize or reduce cover of cheatgrass (*Bromus tectorum*). Percent relative cover of dominant native perennial grasses and cheatgrass were examined to detect postburn trends. This information was summarized for data collected from 1989 through 1994 for one brush monitoring type. A management-ignited fire was conducted in October 1989.

Sagebrush Shrubland

Sagebrush shrubland at Lava Beds is found on north, east, and west aspects, at elevations ranging from 1219 to 1828 meters (4000 to 6000 ft), on midslope, upper slope, and ridge top areas that are relatively open and gently sloping. Soils are derived from pyroclastic debris and basalt and are relatively young with little horizon development. A stone pavement overlies shallow gravely sand to sandy loam. Many basalt outcrops occur within lava flows that are less than 2000 years old. Vegetation is dominated by big sagebrush (*Artemisia tridentata*) with significant cover of native perennial bunchgrasses, typically >10%. Common bunchgrasses include Thurber needlegrass (*Acnatherum thurberiana*), steppe bluegrass (*Poa secunda*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and Idaho fescue (*Festuca idahoensis*). Cheatgrass is abundant. Antelope bitterbrush (*Purshia tridentata*) is common. Common herbaceous species include *Gayophytum ramosissimum*, ashy penstemon (*Penstemon humilis*), and narrow-leafed phacelia (*Phacelia linearis*).

Percent relative cover for the common native bunchgrasses increased by 17% in 13 burn plots over time, indicating a generally favorable response to prescribed fire (Figure 1). This increase meets the park's objective of increasing percent relative cover of dominant native bunchgrasses. Percent relative cover of cheatgrass in burn plots increased from 14% to 19% (Figure 1) within two years postburn, but by the fifth year had declined to 11%, decreasing slightly over time, meeting the park's objective to stabilize or reduce cover of cheatgrass. Note sample size decreased to eight plots for the two-year postburn reading. This is due to a decrease in personnel available to do the job.

In control plots for this monitoring type, percent relative cover remained relatively constant for native bunchgrasses, 37% preburn to 38% five years postburn (Figure 2). This lends support to the opinion that the native perennial grasses responded favorably to the burn. Cheatgrass levels rose sharply, from 7% preburn to 18% within two years postburn and dropped again five years postburn to 5% (Figure 2). Note that the sample size is smaller than the number of burn plots—five plots for preburn and five-year postburn, three plots for two-year postburn. Despite the inadequate sample size, the trend displayed here is in accordance with past research (Martin and Johnson 1976) concerning the small effect that prescribed fire can have on cheatgrass.

SEQUOIA AND KINGS CANYON NATIONAL PARKS

The Sequoia/Kings Canyon National Parks fire effects monitoring program has been ongoing since 1982, seven years before the inception of the Western Region's fire monitoring program. Many of Sequoia's methods and experiences monitoring fire effects were used to help develop the FMH guidelines. The parks' primary prescribed burn objective is 60-80% total fuel reduction, therefore, the primary monitoring variable is total fuel load. As fire exclusion may have changed the composition and density of the mixed-conifer forest in the parks, overstory and pole-size tree densities are examined to detect any changes from prefire conditions that may occur with prescribed burning. Total fuel load and overstory and pole-size tree density are summarized for all data collected through and including the 1994 field season for one of three forest types.

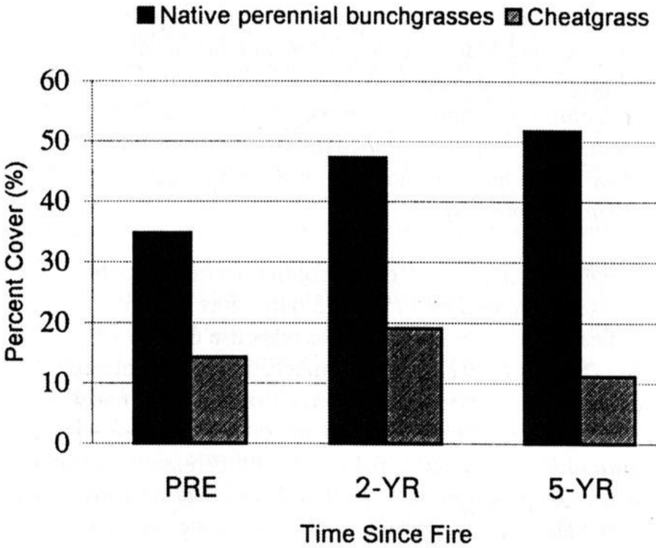

Figure 1. Percent relative cover of dominant native grass species and cheatgrass in sagebrush shrubland burn plots.

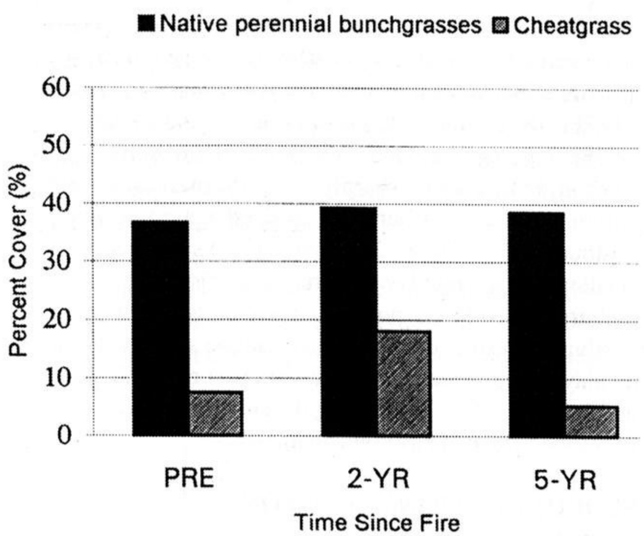

Figure 2. Percent relative cover of dominant native grass species and cheatgrass in sagebrush shrubland control plots.

Giant Sequoia/mixed Conifer Forest

The giant sequoia/mixed conifer forest is located at elevations ranging from 1676 to 2195 m (5500-7200 ft) on all aspects, in drainage bottoms or broad upland basins, occasionally steep slopes and ridgetops. Soil depth ranges from shallow to very deep. Soils are coarse textured and acidic. The giant sequoia type overstory consists of mature white fir (*Abies concolor*), sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa*), giant sequoia (*Sequoiadendron giganteum*), and incense cedar (*Calocedrus decurrens*). The understory is comprised of incense cedar and white fir with black oak (*Quercus kelloggii*). The forest floor is typically sparse, with few herbs, and < 20% shrub cover.

Mean total fuel load in the giant sequoia monitoring type is reduced by 71% following prescribed burning in this forest type, accomplishing the parks' 60%–80% fuel reduction burn objective (Figure 3). Reduction in the duff component was greater than that of the woody component (93% and 56% respectively). After ten years, total fuel load increased to 75% of prefire levels (Figure 4). Woody fuels slightly exceeded prefire levels ten years after burning, while duff accumulated at a slower rate.

Total tree density (three dominant species) was reduced from 498 trees/ha prefire to 295 trees/ ha one year after prescribed fire (Figure 5). Changes in the relative densities of the three dominant tree species varied (note that relative densities do not total 100% as other species are present in small amounts). White fir was 60% prefire and decreased to 56% one year postfire. Giant sequoia relative density increased from 7% to 12%. Red fir decreased only slightly one year postfire. The species' relative densities changed little one to five years postfire. Ten years after burning, the relative density of white fir decreased by 9% (from 60% prefire to 51%) while giant sequoia relative density more than tripled (from 7% prefire to 23%, Figure 5).

CONCLUSIONS

Various methods have been used in national parks to determine the effects of fire on vegetation. In the past, these methods have lasted only as long as personnel implementing them remained at the park. This resulted in a lack of usable information on long-term effects. The current fire effects monitoring program will provide the consistency needed to measure long-term trends in the vegetative response to prescribed fire. Clear, quantitative objectives; accurate, objective observations; and customization of this fire monitoring program will help Pacific West Field Area U.S. national parks meet their objectives and ensure a successful prescribed fire program.

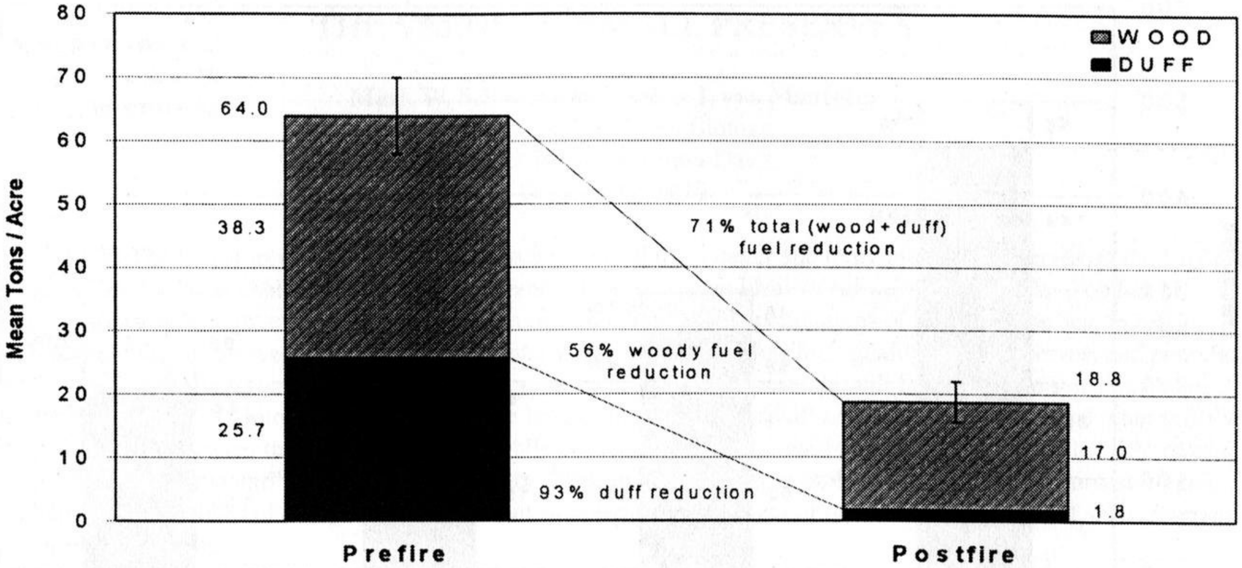

Figure 3. Giant sequoia/mixed conifer forest fuel load reduction (n = 27 plots). Error bars indicate plus or minus one standard error of the mean.

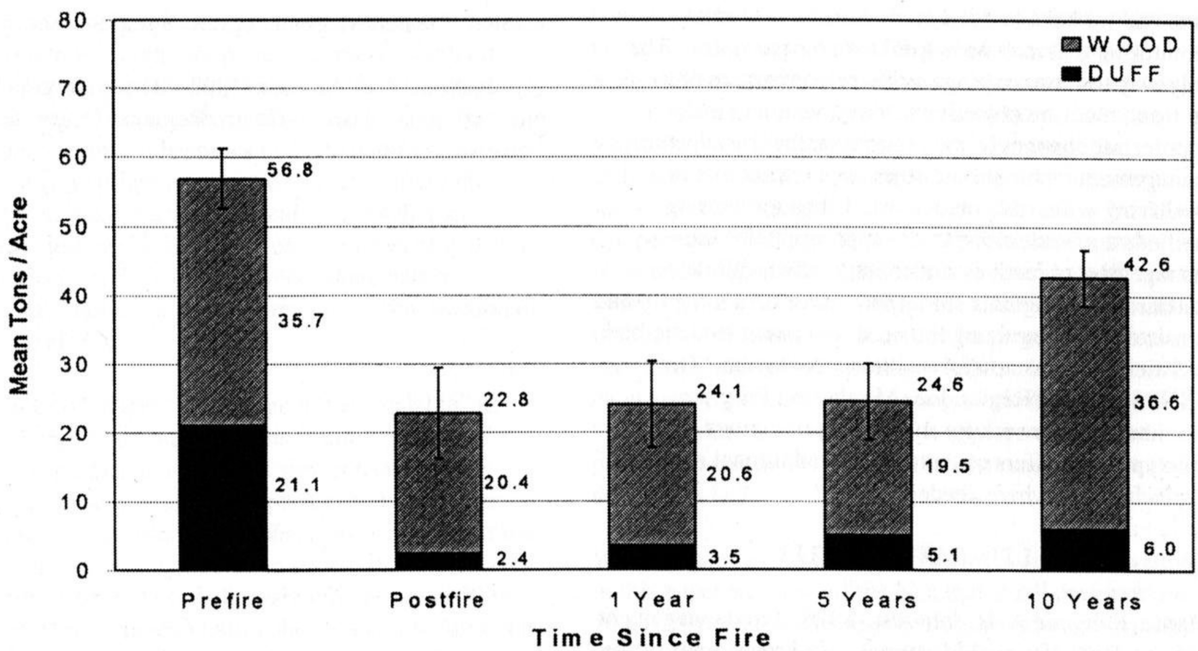

Figure 4. Giant sequoia/mixed conifer forest fuel load accumulation (n = 7 plots). Error bars indicate plus or minus one standard error of the mean.

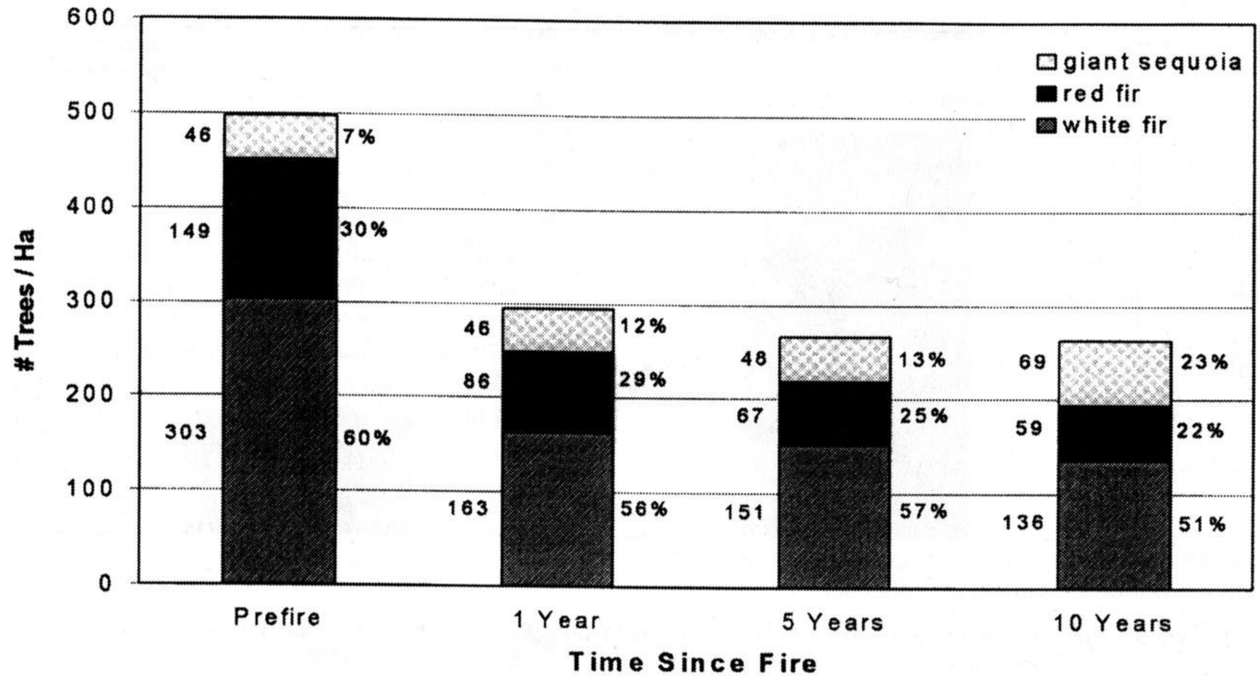

Figure 5. Giant sequoia/mixed conifer forest tree density (n = 7 plots).

The fire effects monitoring program has changed over time and we have learned many lessons related to monitoring that may be helpful for new programs. The only way to monitor program success is to state objectives up front, measure objective achievement, and make appropriate changes to the program, either by adjusting management techniques if objectives are not met or modifying unfeasible objectives. Using monitoring methods and variables that are appropriate for the management objectives is also imperative. While standardized programs are important for data integrity and consistency, recognizing the need for customized methods is critical for a successful monitoring program. The USNPS Western Region Fire Monitoring Program provides a framework for monitoring in various vegetation types and offers consultation on additional monitoring techniques where needed.

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THE VALUE OF SMALL PRESERVES

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ABSTRACT: The recent trend of placing high conservation value on larger and more integrated reserves, at the expense of small isolated sites, is challenged in the case of prairie reserves. In an ideal world we would be able to conserve biological diversity by capturing it on large reserves that contained viable populations of all native species. In reality, most potential prairie reserves of large size are of relatively low quality. Most high quality prairie reserves, and potential reserves, are small. We argue that a unilateral strategy of acquiring prairie reserves will fail to capture some attributes of diversity. While there is biological concern over the long-term viability of small reserves, there are several other positive attributes of small reserves that make them worthwhile conservation targets. Further, small sites may be the sole remaining repositories of some attributes of prairie diversity. Thus, in our attempts to build integrated conservation strategies based on sound principles of ecosystem management, we ought not lose sight of the tremendous value of small reserves for prairie conservation.

Key words: prairie, conservation, reserve size, ecosystem management

INTRODUCTION

The 1990s have ushered in a transition among conservation practitioners from focusing on maximizing quality in preserve acquisition to a "bigger is better" philosophy. Bioreserves, bioregions, biosphere reserves, and sustainable development areas are popular conservation terms for the 1990s. This reasoning leads us to believe only large reserves can maintain viable populations of the natural biota. Thus, it becomes relevant to question whether it is justifiable to expend limited conservation resources on incomplete ecological systems that are potentially unsustainable. This question bears directly on conservation efforts in the Midwest, where natural habitats are fragmented and occupy only a tiny fraction of their original area.

Noss and Cooperrider (1994) urge us to "think big" in pursuing large-scale regional conservation programs. During this past decade we have seen conservation projects increase in scale from species to communities and landscapes, and shift in emphasis from patches of the highest possible quality habitat to sustainable bioreserves of the largest possible size. Remarkably, given the high degree of habitat fragmentation, the Midwest is participating in this large-scale conservation movement. With recent acquisitions of sites like the Nachusa Grasslands, the Cache River, and other bioreserve programs, the midwestern states are doing remarkably well in protecting relatively large pieces of natural habitat.

A recent question of concern in conservation biology has focused on whether small, or isolated, populations are viable (Soule 1987, Menges 1992). Noss and Cooperrider (1994) indirectly pose another question that ought to be central to the field of conservation biology: How small a proportion of the total land mass of a region is required to conserve regional biodiversity—a minimum natural habitat area analysis. The risk in chronically fragmented regions is that they may fall below the minimum requirement. A variety of authors who have focused on large scale wilderness preserves have made estimates, based primarily on personal experience, to suggest that anywhere between 25% and 75% of a region must be dedicated to the maintenance of biodiversity in order to succeed over the long term (sources reviewed in Noss and Cooperrider 1994, pp. 167–172). Within this context, Noss and Cooperrider (1994) refer to reserves with sizes under 1000 ha as "tiny." This poses a serious constraint within the Midwest, where a 1000 ha preserve appears very large, and "tiny" typically refers to sites less than 2 ha in size. If permanently securing biotic diversity requires millions of acres, then it appears that it is not possible to create a viable reserve system across most of the eastern U.S.

While large reserves are key components in conservation, in this paper we forward the idea that small preserves (< 10 ha), even in the most highly fragmented regions, also play a critical role in conservation programs. This recent shift toward large sites has left small conservation organizations and the private landowner on the periphery of the conservation mainstream. Bioreserve projects, being expensive and management intensive, are largely the domain of state and federal agencies. New tools and new approaches are required to address the question of how little habitat, or how isolated, preserves can be and still adequately preserve biological diversity. We do not yet have the answers to these questions. We hope to demonstrate that the real potential for the Midwest to contribute to both conservation and our understanding of conservation biology may lie in its many small preserves.

Conservation Objectives: Are Incomplete Ecosystems Acceptable Conservation Projects?

Ecosystem-based management appears to be a logical and popular approach to protecting biodiversity (Grumbine 1994, Beattie 1995). By virtue of their small size, most midwestern preserves can only encompass incomplete ecosystems. Thus, we must question whether preserving incomplete ecosystems is a worthwhile conservation endeavor or the appropriate planning objective. The answer to this question hinges on conservation goals, which range from saving populations and species to conserving landscape and ecosystem functions. Specific conservation values and goals, however, are often determined at a regional level. Therefore, it is in reference to apparent midwestern conservation objectives that the value of small sites and incomplete ecological systems must be judged.

Although relatively few states have published explicit plans for the conservation of biotic resources, one can nonetheless get a sense of what are considered to be central objectives by examining what information is used to make decisions on preserve acquisition and site management. In Illinois, for example, the Natural Areas Inventory identifies sites for potential acquisition and ranks them by community type (White 1978). These sites are of conservation value because they possess relatively intact communities and not, as a rule, because of the occurrences of endangered species. Neighboring states have followed similar goals with respect to site acquisition. Thus, acquiring representatives of natural communities appears to be the primary functional conservation goal in the Midwest. Capturing populations of threatened and endangered species, as well as a representative coverage of all native biota is a secondary goal.

From a biological standpoint, community-level conservation is useful as a vehicle to simultaneously support native species, genetic diversity, and the biological interactions that provide the raw materials for natural selection and evolution. Small preserves, however, can not support large predators and grazers (i.e., timber wolves, *Canis lupus*; and bison, *Bison bison*). While preserving incomplete communities or ecosystems is apparently socially acceptable conservation practice under the operational rules of conservation in the Midwest, the biotic consequences are not fully understood. Although species requiring large habitat ranges comprise only a fraction of the total species richness, biomass, and numbers of individuals of a given area (Ricklefs 1979), their absence potentially creates problems. In terms of food web dynamics, it is possible that the missing macrofauna may leave gaps in trophic linkages. Yet, disruptive cascading effects caused by the removal of "keystone" predation or herbivory are highly unlikely in complex terrestrial systems (Strong 1992). Lacking evidence to the contrary, community conservation of incomplete ecosystems appears to be at least proximally successful at maintaining native biodiversity.

Preserve Design

The question of how well the extremes of preserve size, small and large, accomplish midwestern conservation goals remains. Much of the scientific literature that pertains uniquely to the conservation of biological diversity has focused on issues related to the size and arrangement of preserves (Soule and Simberloff 1986). Preserve design goals were formalized with five simple rules, the first two of which refer to the assertion that bigger preserves, all other things being equal, are better (Diamond 1975). During the 1980s a debate developed around how to best capture and maintain regional diversity (SLOSS -Single Large versus Several Small preserves—Soule and Simberloff 1986). The maintenance of biodiversity issue currently revolves around two simple observations with opposite predictions. First, larger sites support larger and potentially more stable populations (Pimm 1991). Second, a suite of partially isolated populations (metapopulations) in networks of small sites buffer species from chance extinctions through local catastrophe (Pimm 1991). Much remains to be learned about actual extinction probabilities, movement rates between sites, population stability, and balancing population size and sub-division to minimize extinction probabilities. In the meantime conservation managers are saddled with uncertainty regarding the proper emphasis to place on large versus small preserves.

Within the Midwest, the tiny 2-ha nature preserves have, historically, been assumed to contribute to the conservation of broadscale biodiversity. It is clear, however, that we cannot conserve the full suite of biodiversity on small habitat fragments regardless of habitat quality. This is particularly true of large vertebrates. Very small prairie sites provide habitat for as many prairie plants as the largest high-quality sites (Schwartz et al. 1997), but may lack the area required to maintain these populations through time. Alternately, numerous small sites better capture diversity and species interactions among the broadest array of species than a few large sites (Simberloff and Gotelli 1984, Schwartz et al. 1997).

Large areas set aside for conservation undoubtedly have merit, but small preserves still have much to offer in terms of biodiversity. This is particularly true for plants and invertebrates. Surveys of Wisconsin prairies have shown that there are typically over 200 vascular plant species per community type even in highly fragmented communities (Curtis 1959). Surprisingly, small populations of native

Great Plains plants along railroad rights-of-way and in pioneer cemeteries have been resistant to extinction, particularly when fire has been used to keep the invasion of exotic plants in check (although the consequences of inbreeding and the loss of native pollinators may have unforeseen future effects). In addition, many small replicate reserves may conserve a large variety of local ecotypes.

Preserve Quality, Size, and the Need for Restoration

For land managers, the SLOSS debate has been largely academic; in a very real sense the choice between large and small preserves does not exist. The more pertinent question in the Midwest is whether it is more effective to invest in expanding and/or connecting existing reserves through habitat restoration or to acquire and maintain additional separate areas of the highest possible quality.

Small areas (< 10 ha) are generally of conservation interest because they are high-quality remnants. Conversely, in chronically fragmented habitats large sites are often already degraded. In the Midwest, large sites (> 200 ha) under consideration for acquisition usually require significant habitat restoration. If large preserves are the target of conservation efforts, it can be argued that we should focus on restoring diversity into large sites. Unfortunately, the history of restoring diversity is not promising. After nearly 20 years of work, habitat restoration projects remain relatively depauperate in comparison to intact remnants. Experience with over 50 years of prairie restoration at the University of Wisconsin-Madison Arboretum demonstrate that even with sufficient time, resources, and scientific knowledge, the successful restoration of relatively well-understood communities is by no means assured (Cottam 1987). As an alternative to the reintroduction of entire communities, the preservation of small parcels of intact populations will often be more logically suited for the maintenance of populations of rare or threatened species.

The critical point that gets lost in the search for a clear answer to apply generally is that science can not guarantee the right position on the issue of preserve size and connectivity. The optimal preserve design for a region or a landscape depends on the conservation objective. The answers to current questions surrounding developing a preserve system will only become apparent in the future as decisions are made and their outcomes observed. To undervalue small sites in terms of their potential for maintaining biological diversity would squander an important resource for conservation.

Accessibility of Small Preserves

Several critical attributes of small versus large preserves are independent of science. For example, in order to succeed at global conservation we must enlist widespread popular support. An effective means toward this goal is to personally engage people in the act of saving naturalness (i.e., stewardship) within what people view as their own neighborhood. Providing the opportunity for people to take an active relationship with their natural environment is probably the fastest route in developing the land ethic envisioned by Aldo Leopold (1949). Local participation makes it possible for a wide spectrum of the public to appreciate not only the benefits of, but also their obligations to, the natural landscape. Through an understanding of what it takes to preserve the biotic community in their regions, people come to see the value and cost of preserving nature globally. Extending traditional ethics beyond the human community to encompass the natural landscape is a likely route to success in conserving the stability, integrity, and beauty of our natural areas.

Due to unavoidable logistical problems, suites of small sites require more stewardship than a single preserve of equal area. A positive side to this stewardship burden is that everyone who has the desire to take primary responsibility for management projects on small preserves has the opportunity. There are numerous sites in chronically fragmented regions in need of saving: stewardship going wanting, restoration projects waiting to happen, educational opportunities being missed. With numerous small preserves, the Midwest has a great need for volunteers to help manage biological diversity. It is no coincidence that midwestern states have some of the largest volunteer stewardship networks in the country. In addition, with many small preserves, one of them is usually close to home. In contrast, large reserves frequently require a professional staff as well as a degree of isolation from human populations. While we enjoy large sites, and they also require volunteer assistance, it often takes substantially more effort for the private citizen to develop a personal relationship with large preserves.

An interest in nature seems to be what compels most people to be sympathetic toward conservation. Nobody advocates environmental degradation as a goal; public sentiment is uniformly in favor of a healthy environment (Norton 1994). Where we differ is in regard to the cost we are willing to bear to preserve a healthy environment. Arguments for conservation often invoke the undiscovered potential economic benefits of native species or balanced ecosystems. While these arguments may sway economists, we believe that they are too intangible for most people. What garners support for conservation efforts is focusing attention on the quality of the local environment and educating people on how they can help it improve.

In order to build a conservation constituency we need to provide opportunities for the public to participate in the management of native species and natural lands. A large network of small sites afford us the best opportunity to develop this connection to natural areas among the broadest spectrum of people. Further, it is the caring and nurturing of local biotic resources that often drives our concern for more global conservation issues. In order to accomplish global conservation goals we first need to get as many people as possible personally involved in their local environment. As an added benefit, when people are dedicated to protecting their local natural surroundings, they are much more likely to extend this commitment to the global arena, where their personal actions will inevitably have a less distinct impact.

Flexibility in Management Options on Small Preserves

Conservation biology is, at best, an inexact science that attempts to advise on a broad array of appropriate conservation objectives. While we do not have all the answers, large suites of small preserves provide the opportunity to remain flexible and experimental regarding preserve management. An obvious outcome of having many small nature preserves is that management plans must be written for each preserve. This difficult process of articulating specific conservation goals is the first step in establishing standards by which to measure success of conservation actions. The process of delineating goals is difficult, in part, because there is a patchwork of views encompassed by the term "conservation." Goals under the rubric of conservation can, in certain circumstances, be in conflict with one another (Hobbs and Huenneke 1992, Schwartz 1994). In addition, this patchwork of values and goals is continually changing. For example, creating forest openings and feed plots for deer was a primary conservation management activity just 30 years ago, but is rarely endorsed for conservation at the present time. Further, management strategies to achieve specific objectives are not always clear. Uncertainty regarding the best means to achieve conservation objectives, as well as variation in objectives, is a compelling argument in support of establishing smaller replicate preserves rather than a few large preserves. This is the core idea behind "adaptive management" (Holling 1995) where our ignorance concerning ecological systems is acknowledged and a variety of management options are pursued in the attempt to observe which strategy works best.

When translating these differences of opinion regarding management into a preserve system, there are many ways in which our cultural need for open space may be made manifest. Some satisfy their needs through hunting or fishing. Others seek to view the expansive openness of a large tract of natural habitat in order to imagine the splendor of the pristine American wilderness. Still others prefer the details of the prairie, the small intricacies of the forest—the spiders, butterflies, birds, and squirrels. A small patch of woods close to home often ideally suits this latter need.

In this spirit, there remains a debate regarding what constitutes a prairie. Is a prairie defined by its complement of herbivores, requiring the presence of bison? Are large, low-diversity grasslands prairies? How dominant can woody invaders or exotic species be in grasslands before we stop calling a site a prairie? Illinois Natural Heritage biologists have a system of assigning quality grades to prairies (White 1978). This subjective grade assignment to sites is fairly consistent and predictable. In contrast, how we assign grades to prairies in our own hearts and minds is undoubtedly variable. The Wolf Road Prairie in Chicago provides an excellent example. A 32-ha grassland site was passed by for development during the 1930s owing to a complex set of legal problems. By the 1960s the site was well within the urbanized metropolitan area. The prairie, due to lack of management, was badly degraded from a formerly pristine site, but still retained significant biotic resources and potential for recovery. Under the threat of development, a private citizens group (Save the Prairie Society) began to acquire the more than 100 deeds that comprised the site. In 1993 the Wolf Road Prairie was dedicated as the 230th nature preserve on the 30th anniversary of the Illinois Nature Preserves Commission. While the site is now of only moderate biological quality, the site is widely recognized as one of the most important additions to the Nature Preserve System in Illinois because it: 1) represents the culmination of a huge private conservation effort; 2) provides an excellent site for prairie recovery efforts; and 3) is readily accessible to several million people. While the habitat quality of Wolf Road Prairie may not be particularly impressive, one is awed by the spectacle of such wildness persisting within an urban setting.

Private Land Owners as Stewards of Biological Diversity

The Midwest enjoys a remarkable legacy of ecological thought, natural history study, and conservation action. This legacy has developed around aggressive acquisition programs that targeted the highest quality sites and incorporated them into networks of nature preserves. For example, the Illinois Nature Preserves Commission began in 1963 to formulate the structure for a diverse array of dedicated nature preserves that had grown to more than 230 sites by 1994. A primary concern of governmental bodies, however, must be whether they are able to manage the resource. From a management perspective, it appears that a few large sites enjoy a considerable advantage over numerous small sites. This observation is not lost on state agencies acquiring natural habitats. Ownership of Illinois nature preserves is split among the state (97 preserves), various municipal bodies (such as County Forest Preserve Districts - 95 preserves), and private individuals and organizations (44 preserves). These entities, however, do not all own the same types of nature preserves. Nearly 88% of state-owned nature preserves are greater than 20 acres in size, 75% of municipally owned nature preserves are greater than 20 acres, while only 32% of privately held nature preserves are greater than 20 acres in size (Figure 1). Though individually small in size, one cannot disregard the importance of the private landowner; only one-third of the total landmass in the U.S. is federally owned (Shafer 1994). Small nature preserves are the forte of the private conservation effort. Indeed, the privately owned and managed Heron Lake preserve in Minnesota has provided a model for wetland conservation in the region (Rich Beilfuss, pers. comm.). The predominant forest owners in Illinois are private individuals who, on average, own about 20 acres and value their land predominantly for wildlife habitat and preservation (Iverson et al. 1989). We need to foster these private conservation activities, and this means encouraging the establishment of small preserves.

CONCLUSIONS

In Illinois, the rate of acquisition of small sites by state, municipal, and private owners peaked during the years 1985–1989 (McFall 1991). Small site acquisition has dramatically trailed off during the 1990s. Yet, the job of acquiring and preserving small remnants of high-quality natural habitats in Illinois is not complete. This slowing of small site acquisition may indicate that the private sector, which assumes primary management responsibility of these small preserves, is saturated. We do not think that this is a sufficient explanation. Natural resource agencies in Illinois are concentrating efforts on larger-scale projects. This shift in emphasis forces us to question whether small sites are failing as nature preserves. Current evidence does not suggest that biological diversity is being lost on small sites. Small prairie sites appear to be as diverse as large prairies and are able to maintain their diversity (Robertson and Schwartz 1994). Thus, we appear to be focusing on larger, lower-quality sites for reasons other than the failure of small sites. We contend that many of the big bioreserve projects are popular not because of scientific or management arguments, but because we envision large sites as satisfying a wide variety of conservation objectives, both biological and recreational. Unfortunately, these large sites seem destined to fall short of expectations because our diverse expectations for these sites are not always compatible. There are, of course, good reasons for acquiring large preserves (Noss and Cooperrider 1994), but the failure of small sites to contribute to the conservation goals of maintaining biodiversity is not one of them. In contrast, an abundance of small sites provides the unique opportunity to experiment with varying management strategies for differing conservation objectives. Further, small sites in urbanized areas provide the arguably best opportunity for engaging human resources in conservation, and we argue, this ought to be a principal goal of biological conservation in chronically fragmented regions.

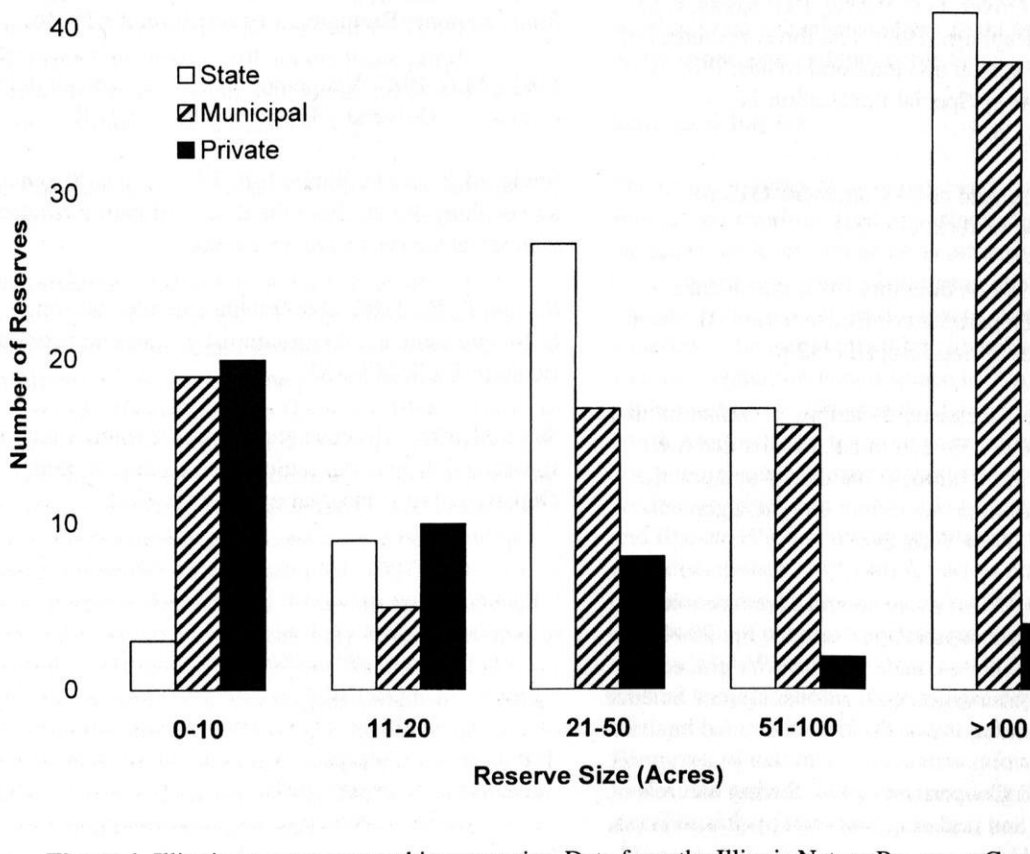

Figure 1. Illinois preserve ownership categories. Data from the Illinois Nature Preserves Commission.

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INTEGRATED CONTROL OF PURPLE LOOSESTRIFE IN MINNESOTA

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ABSTRACT: Purple loosestrife, *Lythrum salicaria* L., an exotic perennial plant of European origin, is invading and degrading a variety of wet prairie and wetland habitats across North America. Purple loosestrife can form dense monotypic stands replacing native plant species, thus, degrading food, shelter, and nesting sites for wildlife. Control efforts such as cutting, burning, and herbicide applications have been attempted with limited success. Armed with new knowledge of the biology of purple loosestrife and the emergence of biological control, new integrated vegetation management strategies have been developed to manage purple loosestrife. The methods include managing purple loosestrife by watershed, utilizing hand removal, herbicides, and biological control techniques.

Key words: purple loosestrife, integrated vegetation management, biological control, herbicide

INTRODUCTION

Currently there are no chemical or mechanical methods, such as hand pulling, that provide long-term control of established stands of purple loosestrife. However, biological control, the use of natural enemies to control a pest, shows promise as a long-term method of reducing the impact of purple loosestrife on our native wetland environments. Since 1992, four species of European insects , one root-mining weevil, one flower-feeding weevil, and two leaf-feeding beetles, have been released in Minnesota to control purple loosestrife. The introduction of these four insects will not eradicate purple loosestrife, but if successful, will significantly reduce its abundance within wetland habitats.

Purple Loosestrife Introduction and spread in North America

Purple loosestrife, a showy perennial, is a native to temperate regions of Europe and Asia (Thompson et al. 1987). The introduction and spread of purple loosestrife in North America follows the same pattern as that of many other exotic plants and animals (Laycock 1966). They are closely associated with the migration of people across the ocean and their subsequent settlement of the continent. A major source may have been seed transported in the ballast of ships carrying goods and people between the Old and New Worlds (Thompson et al. 1987). In addition, purple loosestrife was valued as an ornamental or herb in Europe and immigrants may have intentionally introduced plants to North America (Thompson et al. 1987). Purple loosestrife first became established on the east coast in the early 1800s but soon spread progressively westward and now occurs in nearly every state and Canadian province (Stuckey 1980). The heaviest infestations are found in the northern half of the U.S. and southern Canada.

Because of purple loosestrife's appeal as a perennial garden plant, intentional introductions played a major role in its spread. It is a striking plant, hardy, tolerant of a wide variety of moisture and nutrient regimes, and in North America, virtually free of insect pests and diseases. These attributes, which led to the development of over 20 different cultivars, are the very ones that make this plant such a formidable invader (Anderson and Ascher 1991, Ottenbreit 1991, Skinner et al. 1994). Purple loosestrife also has been valued as a honey plant because of its long blooming season and numerous flowers (Bunch 1977).

Ecological Impacts

The negative impacts on aquatic and seasonally wet ecosystems resulting from invasions of purple loosestrife far outweigh its attributes as an attractive ornamental or productive honey plant. Thompson et al. (1987) initially documented the ecological impacts of loosestrife in North America. The initial effect this plant has on native wetland vegetation is to displace it. Unlike its growth pattern in Europe, the growth of purple loosestrife in North America is so vigorous that native wetland species are outcompeted. Purple loosestrife produces large seedbanks which can stay viable for many years (Welling and Becker 1990) allowing the plant to recover quickly after disturbance. In North America, purple loosestrife can form dense monotypic stands eliminating virtually all other wetland plants. Common plants such as cattails, sedges (*Carex* spp.), and smartweeds (*Polygonum* spp.) as well as vulnerable rare plant species dependent on natural wetland habitats cannot compete with purple loosestrife. Examples of natural communities infested by purple loosestrife include wet meadows, sedge meadows, calcareous fens, emergent marshes, and flood plain forests (Skinner et al. 1994).

Animals that rely on the native vegetation for food, shelter, and breeding areas cannot use areas heavily infested with purple loosestrife (Thompson et al. 1987). Waterfowl do not feed on loosestrife (McKeon 1959, Friesen 1966, Malecki and Rawinski 1979). Other species of birds that are dependent on marshes or wetlands, such as marsh wrens (*Cistothorus palustris*), black terns (*Chlidonias niger*), least bittern (*Ixobrychus exilis*), and rails and grebes will neither nest nor feed in wetlands dominated by purple loosestrife (Hickey 1997, Lor 1999, Rawinski and Malecki 1984, Whitt et al. 1999).

DISCUSSION

Conventional Control

Conventional control methods for purple loosestrife such as cutting, burning, water-level manipulation, and herbicide treatments have been largely unsuccessful except where small isolated stands can be removed by hand or treated with herbicides (Gagnon 1953, McKeon 1959, Smith 1959, Malecki and Rawinski 1985, Skinner et al. 1994). Conventional methods do kill purple loosestrife plants. However, once purple loosestrife has become established in a wetland, its large seed bank allows rapid re-establishment that is nearly impossible to eradicate. Research done by the University of Minnesota demonstrated that long-established stands of loosestrife develop very large and persistent seed banks (Welling and Becker 1990). Repeated attempts to control these infestations mechanically or with herbicides are very costly, must be repeated each year, and do not provide reliable long-term control (Skinner et al. 1994).

Beginning in 1991, the Minnesota Department of Natural Resources (MDNR) developed a prioritization plan for selecting loosestrife infestations to be controlled with herbicides. This was done because there are insufficient resources to apply herbicides to all purple loosestrife infestations in Minnesota. In addition, herbicides had little apparent long-term impact on loosestrife when applied to large populations that had been established for a number of years and had developed large seed banks. Consequently, small and recently established populations of loosestrife, which are likely to have small seed banks, are given the highest priority for treatment. Because purple loosestrife spreads mainly by seed in water, watersheds with the fewest number of loosestrife infestations are treated first to limit spread within these relatively un-impacted wet areas. Within a watershed, loosestrife infestations located in the upper regions are treated first to prevent spread downstream and re-infestation of sites that are being controlled.

The most effective herbicide for the control of purple loosestrife is Rodeo®, or glyphosate, which is a broad spectrum herbicide that is also toxic to desirable, native plants. To allow maximum survival of native plants, Rodeo® is most frequently applied by backpack sprayer as a "spot- treatment" to individual loosestrife plants. A second herbicide, 2,4-D, or 2,4-dichlorophenoxyacetic acid, also has been used because it affects primarily broad-leaved or dicotyledonous plants and therefore would be less detrimental to native plants such as cattails. Control efforts in Minnesota, however, suggest that 2,4-D herbicide is less effective than Rodeo®, and therefore is not frequently used (Skinner et al. 1994).

Biological Control

Classical biological control techniques reunite pest species like purple loosestrife with their natural enemies to reduce the pest population to an acceptable level. Plant competition and existing enemies, such as insects, can keep many plant species introduced outside their native range from becoming pests. Biological control, if successful, will not eradicate purple loosestrife but will significantly reduce the plant's negative impacts on the ecosystem (Malecki et al. 1993).

Research was carried out in Europe during the mid-1980s to determine the suitability of potential biological control agents for introduction into North America. Two primary criteria are used to determine suitability. The insects need to: 1) be host specific—survive and feed exclusively on purple loosestrife and do not pose a threat to native North American plant species, and 2) cause significant damage to purple loosestrife—cause plant mortality, reduce shoot growth, suppress flowering, and/or reduce seed output.

Of the 120 species of insects found to be associated with purple loosestrife in Europe, 5 species were considered the most promising for biological control (Batra et al. 1986, Malecki et al. 1993). These species are a root-mining weevil, *Hylobius transversovittatus*, two leaf-feeding beetles, *Galerucella calmariensis* and *G. pusilla*, and two flower-feeding weevils, *Nanophyes marmoratus* and *N. brevis*. All five species were thoroughly tested and determined to be host specific and were cleared for release in the U.S. by the Animal and Plant Health Inspection Service of the United States Department of Agriculture and in Canada by Agriculture Canada (Hight 1995, Malecki et al. 1993).

Insects were chosen that attack different parts of the plant. The root-mining weevil attacks the main storage tissue of purple loosestrife, the leaf-feeding beetles defoliate the plant and reduce flower production, and the flower-feeding weevils destroy the flowers and reduce seed production. A combination of insects that reduces the vigor and reproductive potential of purple loosestrife in different ways is more likely to provide an acceptable level of control than one insect alone. Of the five species, the root-mining weevil and the leaf-eating beetles will be the most important for the control of purple loosestrife due to the damage they cause to purple loosestrife roots, leaves, and stems (Malecki et al. 1993).

In 1992, both leaf-feeding beetles and the root-mining weevil were released in Minnesota. All three insect species have survived harsh winters and have become established in Minnesota. The flower-feeding weevils were approved for release in 1994 and one species, *Nanophyes marmoratus*, was released into Minnesota. The flower feeders became established in 1995.

CONCLUSIONS

Since 1992, over 2 million leaf-feeding beetles have been reared and released in 40 counties in Minnesota. The insects are released by watershed in loosestrife infestations that are well established and uncontrollable with herbicides. The MDNR's immediate goal is to establish the biological control agents in every infested watershed (more than 65 watersheds) in Minnesota by the year 2000. MDNR's statewide and local rearing efforts will be necessary to accomplish this goal. The MDNR provides insect rearing starter kits to cooperating federal, state, and local government agencies that can then rear and distribute biological control agents to their local loosestrife infestations. Localized rearing efforts have dramatically increased the number of insects reared and released in Minnesota—from 200,000 leaf-beetles in 1996 (by MDNR alone) to 1 million leaf-beetles in 1997 (with cooperators). In Minnesota, county agricultural inspectors, state resource managers, federal wildlife refuge managers, and Indian tribal governments play an important role in this project.

Several of the leaf-eating beetle releases made in 1994 showed significant control of purple loosestrife in 1998. This included a 95%–100% reduction in flowering, a 50% reduction in plant height, and total defoliation of stands of loosestrife. Long-term monitoring is under way at locations statewide to document changes to purple loosestrife, biocontrol insects, and native plant communities.

Biological control of purple loosestrife in North America will take time. Researchers believe that changes may be seen in small wetlands within five to seven years after insects are released, but on a national scale, it may take 20 years before significant progress is seen. If successful, biological control will provide long-term control of purple loosestrife. Malecki et al. (1993) predicted "a reduction of purple loosestrife abundance to approximately 10% of its current level over approximately 90% of its range" due to the introduction of biological control agents. If this prediction is only half correct, many resource managers would consider it a success.

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NINETEEN YEARS OF PRAIRIE RE-CREATION AT FERMILAB: A QUANTITATIVE ASSESSMENT

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ABSTRACT: Prairie re-creation on agricultural land was begun in 1975 and now encompasses over 1000 acres. Practices developed here have been used in many re-creations and restorations since then. Despite the influence of this project, little quantitative evaluation of success and progress has been conducted. In 1993, the presence/absence of all species in a random subsample of the 13 oldest areas (tracts) was taken. Five hundred twenty-two 1-m^2 samples were analyzed both within and among tracts. Two native prairie communities were sampled in a similar manner for comparison. In comparison to the two natural areas, species diversity, including exotic species, was consistently lower at Fermilab while the ratio of exotic/native species was consistently higher. In general, using Jaccard's coefficient of similarity, older tracts tended to be more similar to older tracts than younger tracts, but there were exceptions. Using only Fermilab tracts, there was no trend of an increase in diversity or a decrease in the exotic/native ratio as age increased. Within tracts, samples became increasingly different, as tracts became older.

Key words: species richness, Fermilab, restoration, tallgrass prairie, grassland

INTRODUCTION

The goal of many restorations is to construct a natural community that resembles the one present just prior to European settlement and to establish populations of specific species for their preservation. One of the oldest and largest such re-creations is at the Fermi National Accelerator Laboratory in Batavia, Illinois. The size and age of this re-creation have given it widespread attention and influence. Despite this, no published quantitative data exist to evaluate restoration progress. Nineteen years of replicated plantings should also be useful in testing various models of succession as ecological management is largely the manipulation of succession (Luken 1990, Miles 1987). Baseline data were collected and analyzed in an attempt to detect successional trends in the vegetation. Two native plant communities were sampled to be used for approximate target communities for such a re-creation.

METHODS

Sites

The Fermi National Accelerator Laboratory encompasses approximately 2600 ha of previously cultivated land. Two hundred ha, located in the interior of a particle accelerator ring, were seeded to re-create tallgrass prairie typical of the region prior to European settlement. Seeding was begun in 1964 with local, hand-collected seed. This was done annually for different tracts until 1967, when seeds could be harvested from the first seeded tract. This process resulted in similar but not identically seeded tracts over 15 years. As land was cultivated for at least 100 years prior to seeding, early successional species with seed banks were likely to be widely and uniformly dispersed. Tracts range in size from 5 ha to 24 ha. For soil composition and other details see Jastrow (1987).

For comparison to semi-natural communities, the approximate goal of the re-creation at Fermi Lab, two sites were selected—Wolf Road Prairie and Paintbrush Prairie. Paintbrush Prairie is a sandy-loam and loam prairie located within a historic glacial lake plain (Mapes 1979). Wolf Road Prairie is a silt-loam, prairie-oak woodland complex outside the lake plain area (Bowles 1996). All three areas are actively managed and frequently burned.

Sampling

Each tract was sampled for presence/absence of all species in 1-m^2 plots. Transects were randomly placed within 50-m increments along tract boundaries. Distances to plots along each transect were randomly selected within each 50-m interval. At least one sample was taken for each 0.4 ha. for a total of 547 plots.

Analysis

The similarity of samples was determined using Jaccard's index of similarity (Ludwig and Reynolds 1988). For similarity between tracts, the means of all pair-wise comparisons of each plot for each species present were used. This often resulted in hundreds or thousands of values used to compute each mean. Within-tract similarity was calculated by pairing all plot combinations within a tract. Some tracts had very wet areas while others did not. Because of this, entire plots that contained obligate wetland species (Swink and Wilhelm 1994) were omitted from analysis. This included the genera *Eleocharis*, *Scirpus*, *Typha*, and *Phalaris*. Differences among plots were tested using one-way ANOVA. Normality was tested using the Kolomogorov-Smirnov Lillifores test. The exotic/native ratio could not be normalized and was analyzed using Kruskal-Wallis one-way ANOVA. Analyses were conducted on SYSTAT 5.03 (Wilkinson 1991).

RESULTS

Diversity

Species diversity remained similar except for the two semi-natural areas, where diversity was significantly higher ($p < 0.001$ DF=14; Figure 1). The exotic/native ratio was significantly lower ($p = 0.008$ $F = 9.86$; Figure 2) for the two semi-natural areas, but at Fermilab the ratio was variable with no apparent trend (Figure 2).

Compositional Similarity

Individual tracts were generally most similar to the tracts of intermediate age, however, some of the youngest tracts tended to be more similar to other young tracts (Figure 3). The two semi-natural areas were very similar to each other but were equally quite different from each Fermilab tract. Excluding the semi-natural areas, similarity within tracts decreased at a nearly significant rate ($r = -.524$, $n = 13$, $p = .066$; Figure 4).

Among individual species (Figure 5), an annual, *Ambrosia artemisiifolia*, peaked early and then declined, as did *Melilotus alba*, a biennial. Neither of these species were found in either semi-natural area. Of three species associated with disturbance (Mohlenbrock 1986, Swink and Wilhelm 1994), *Asclepias syriaca* declined with tract age while *Solidago altissima* and *Poa pratensis* remained frequent even in the semi-natural areas. A major dominant in prairies, *Andropogon gerardi*, peaked late and remained high.

DISCUSSION

The re-creation at Fermilab can be looked at in two ways. One way is in relation to the prairie remnants that were sampled and the other is by itself, examining trends among tracts.

In comparison to remnants, low plant species diversity is most likely due to two different aspects of the re-creation. Only a few species dominate the majority of the areas, with *Andropogon gerardi* being most dominant. As a result, most of the seeds reaching the ground are of the most dominant species. In established prairies very few seedlings are found (Clements and Weaver 1924, Goldberg and Werner 1983). Even when an area allows for new plant establishment, the probability is that it will be the most dominant species. As the method of introducing new species (hence, more diver-

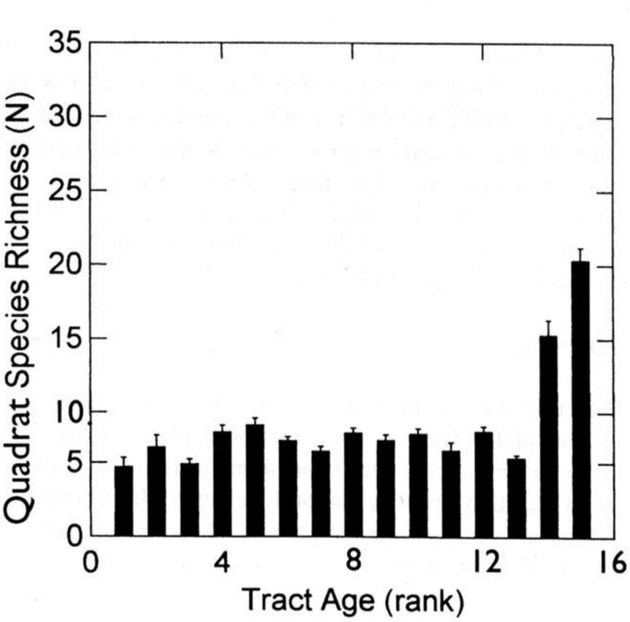

Figure 1. Within 1-m^2 plot diversity ± 1SE, of sampled plots at Fermilab, Wolf Road Prairie (age 14 years) and Paintbrush Prairie (age 15 years).

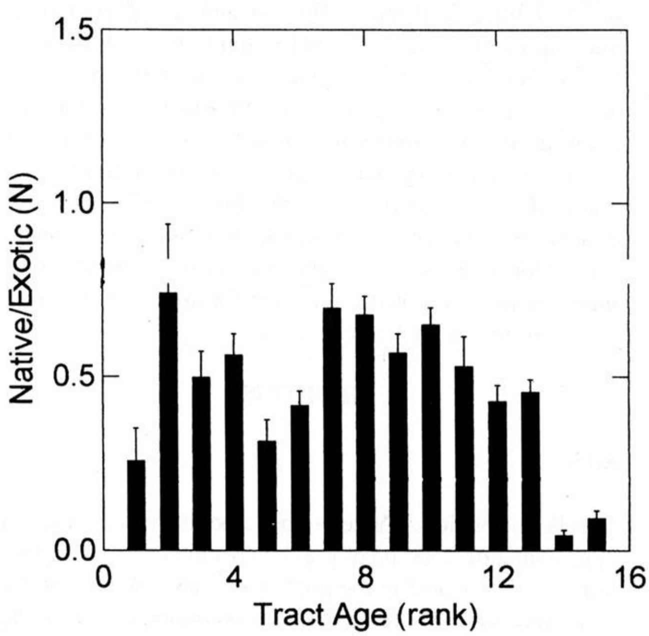

Figure 2. Ratio of native/exotic + 1SE, based on Swink and Wilhelm (1994), for sampled 1-m^2 plots at Fermilab, Wolf Road Prairie (age 14) and Paintbrush Prairie (age 15).

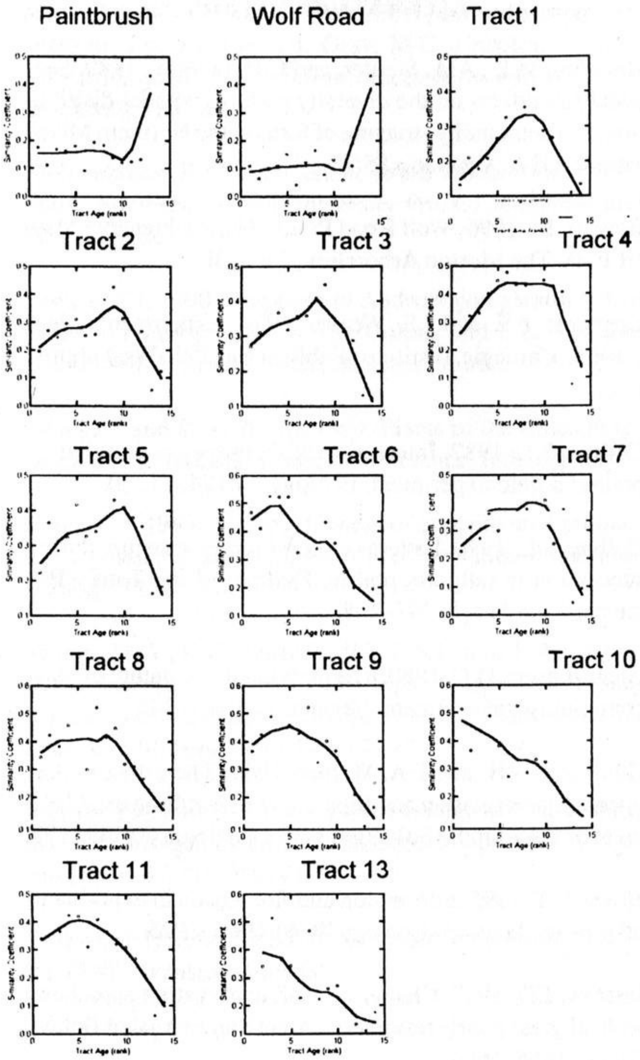

Figure 3. Mean Jaccard's similarity coefficient for each tract compared to all other tracts.

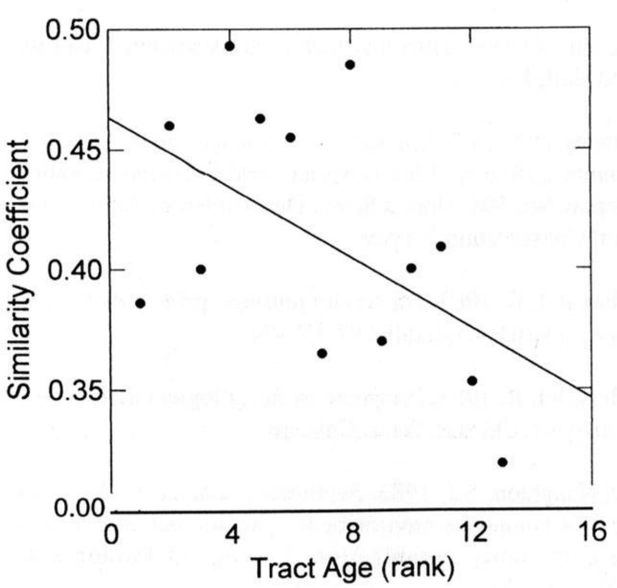

Figure 4. Linear regression of the mean Jaccard's similarity coefficient for within-tract plots at Fermilab only.

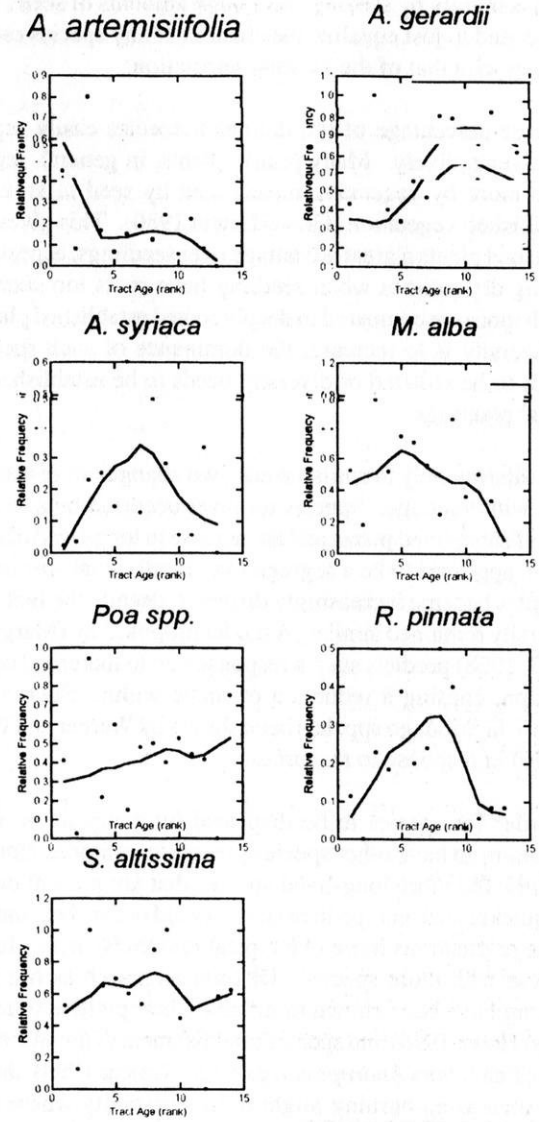

Figure 5. Relative frequencies for various species at Fermilab. *Ambrosia artemisiifolia, Andropogon gerardi, Asclepias syriaca, Melilotus alba,* Poa *pratensis* and *P. compressa, Ratibida pinnata, Solidago altissima.*

sity) is mainly by seeding, very large amounts of seeds will be needed to just equalize the chances of any species establishing with that of the existing vegetation.

A large percentage of the dominant species easily reproduce vegetatively. Many prairie plants, in general, reproduce more by vegetative means than by seed in areas of established vegetation (Glenn-Lewin 1980). This gives established plants a great advantage over seedlings, especially during dry periods when seedling have roots too short to reach moisture compared to deeply rooted established plants. If diversity is to increase, the dominance of such species needs to be reduced or diversity needs to be established at initial plantings.

Considering only Fermilab areas, two changes were associated with tract age. Species turnover occurred by a reduction of short-lived plants and an increase in long-lived plants. There appeared to be a segregation of individual species as samples became increasingly different, despite the fact that diversity remained similar. A model proposed by (Margalef 1963, 1968) predicts such a response due to increased competition, causing a reduction of niche width. Such a response in Solidago spp. has been shown by Werner and Platt (1976) in response to resources.

In order for species to be displaced by competition, it is necessary to have other species present to compete. Consequently, the more long-lived species that are present early, the quicker such competitive shifts should occur. This should make re-creations more like typical remnants, increasingly diverse with more species. Disturbances such as fire and grazing have been shown to influence competitive interactions (Howe 1995) and species establishment (Tilman 1993). Fire often favors *Andropogon gerardi* (Svejcar 1990), therefore increasing burning might reduce diversity where it is very dominant (Collins 1987, Biondini et. al. 1989). Studies on grazing have shown that it reduces dominant vegetation (McNaughton 1983, Collins 1990), particularly grasses (Vinton et. al. 1993). It therefore seems possible that grazing or disturbance similar thereto may act to achieve remnantlike diversity more rapidly than burning.

Controlled experiments have been set up at Fermilab to investigate the effect of removal of aboveground biomass during the growing season on long-lived perennial establishment.

CONCLUSIONS

Species richness at the 1-m^2 scale is not increasing at Fermilab. As time proceeds, species richness is declining, likely due to increasing spread and dominance of a few species. This is different from the situation found in prairie remnants, where richness is higher. Further study is needed to determine the mechanisms by which this high richness is accomplished.

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CHARACTERISTICS OF EXOTIC PEST PLANTS

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ABSTRACT: We compiled 22 characteristics of exotic pest plants from a number of sources. From generalized pollination systems and effective seed dispersal mechanisms to high reproductive rates and rapid growth, exotic pest plants share many characteristics. Explanations or examples provide a better understanding of each of these characteristics for people interested in exotic pest plant species management.

Key words: exotic pest plants

INTRODUCTION

Many of the exotic pest plants present in our remnant native communities were brought here from Europe and other parts of the world as ornamentals or contaminants in agricultural seed (Mack 1990). It is also well known that conservation agencies have used exotic species widely for wildlife habitat and soil conservation (Dantonio and Vitousek 1992, Harty 1986). Despite added assurances during initial promotion, multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*), bush honeysuckle (*Lonicera tartarica*), Amur honeysuckle (*L. mackii*), and many other species, have become nuisances (Harty 1986).

Not only can exotic species contribute to the degradation of the landscape, but they may be harmful to livestock and lead to economic losses. For example, leafy spurge infests 1.2 million acres of rangeland in North Dakota alone, and results in estimated annual losses of nearly $9 million (Cheater 1992). Tall fescue (*Festuca arundinacea*) now occupies more than 35 million acres in the U.S. and results in losses up to $1 billion annually of both rangeland and livestock (Ball et al. 1993).

Represented above are only two of many exotic pest plant species, and the estimated annual losses from these two species amount to $1.9 billion. This dollar estimate does not, however, include the cost of controlling these pests. If the costs for the number of work hours and other logistical support (e.g., herbicides, fuel) were added to the above figure, the realized economic loss alone would be much greater.

Exotic species share many characteristics. By reviewing the literature, we have developed the following list of characteristics of exotic species to provide restorationists, land managers, ecologists, and others interested in exotic pest plants a background and understanding of these plants.

Characteristics of Exotic Pest Plants

1) **Similarity in climate, soils, and lifeform** — Many exotic species survive and spread because conditions in North America are similar to those in their land of origin (Wagner 1993).

2) **Generalized pollination systems** — Many exotic species have simple pollination systems and do not require a narrow range of environmental conditions or a specific pollinator to become fertilized (Newsome and Noble 1986).

3) **Effective seed dispersal mechanisms** — Many exotic species have barbed structures on their fruits, are very palatable to wildlife, or, are readily used by man, which ensures effective dispersal (Wagner 1993, Mack 1992, Werner 1992, Newsome and Noble 1986).

4) **Effective breeding systems** (i.e. facultative apomixis, agamospermy) — Many exotic species are capable of asexual reproduction, i.e. do not require cross-fertilization, or reproduce vegetatively (Wagner 1993, Newsome and Noble 1986).

5) **High interspecific competitive ability** — Many exotic species can out-compete and reduce or

eliminate more desirable native species (Newsome and Noble 1986).

6) **High intraspecific competitive ability** — Many exotic species can withstand and surmount high densities of themselves (Newsome and Noble 1986).

7) **High reproductive rates** — Many exotic species produce numerous seeds (> 100,000 for *Lythrum salicaria* per plant per year) or vegetative offshoots compared to native counterparts (Armine and Stasny 1993, Thompson 1987, Newsome and Noble 1986).

8) **Rapid growth** — Many exotic species can grow very fast and soon over-take or shade more desirable native species (Cronk and Fuller 1995, Newsome and Noble 1986).

9) **Environmental plasticity** (growth) — Many exotic species are tolerant of broad ranges of environmental conditions (Mack 1992, Newsome and Noble 1986).

10) **Environmental plasticity** (reproduction) — Many exotic species can flower and set seed under broad ranges of environmental conditions or when very small or very large.

11) **High speed reproduction** — Many exotic species can grow, flower, and set seed in a very short period of time, resulting in the production of several generations in one growing season (Newsome and Noble 1986).

12) **High pollen and seed viability** — Many exotic species produce pollen and seeds which remain viable for great lengths of time (many years) increasing opportunities for successful reproduction (Newsome and Noble 1986).

13) **Few threats** — Many exotic species have escaped from fungi, diseases, parasites, insect predators, and other herbivores which controlled their growth and reproduction in their homeland, and without these controlling mechanisms with which to contend in North America, they can grow rampantly (Mack 1992, Janzen 1986).

14) **Disturbance** — Many exotic species are associated with disturbed habitats, e.g., disturbed soils and removal of a natural process from a community or ecosystem (Cronk and Fuller 1995, Wagner 1993, Janzen 1986, Swincer 1986).

15) **Long distance traveled** — Many exotic species are far from their original homeland (Wagner 1993).

16) **Only a few within a genus are actually a problem** — One or few species within a taxonomic genus are actually invasive even though the genus may be species rich (Wagner 1993).

17) **Still a weed** — Many exotic species are considered pests in their homeland (Wagner 1993).

18) **Go forth and multiply** — There is little solid evidence that invasive populations will ultimately come into equilibrium with their new associates and then function as nonaggressive members of their communities (Wagner 1993).

19) **Change in biodiversity** — Many exotic species may affect biodiversity at the same trophic level; the trophic level above and/or the trophic level below (Pimm 1986).

20) **Delayed high reproduction** — Many exotic species may not appear to be a problem for many years, but may eventually adapt sufficiently to become naturalized and spread into the landscape (Wagner 1993).

21) **Tolerant of defoliation** — Many exotic species have a great tolerance for partial defoliation and grazing (Armine and Stasny 1993).

22) **Tolerant seeds and seedlings** — As with adult plants, the seeds and seedlings of many exotic species are tolerant of broad ranges of environmental conditions (Newsome and Noble 1986).

CONCLUSIONS

Not all invasive exotic plants have all of the above characteristics. However, experience has shown that a great many invasive species harbor several of these characteristics. That is why we often have a difficult time controlling those species in a short period of time. Hopefully restorationists, land managers, ecologists, and others interested in exotic pest plants will find this list useful; perhaps as a tool to support legislation to restrict the import and sale of invasive exotic species.

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IMPLICATIONS OF EXOTIC PEST PLANTS

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ABSTRACT: A list of 14 implications of exotic pest plant species was compiled from a wide range of sources. From changes in species composition and alteration of a fire regime to diseases and economic losses, implications of exotic pest plants can be local or far reaching. Explanations or examples are given to provide restorationists, nurseries, researchers, and land managers a better understanding of the implications of exotic pest plants.

Key words: exotic species

INTRODUCTION

Many exotic species have become pests in North America and once established, these plants can have various effects upon the landscape, ecosystem, community, or even the species scale.

Purple loosestrife (*Lythrum salicaria, L. virgatum*) is one example of an exotic species that has invaded wet meadows, pastures, marshes, streams, river banks, lake shores, and ditches. Purple loosestrife will invade wetlands to the near total exclusion of most other vegetation; it literally shades out everything else out. Once a wetland is invaded, numbers of traditional residents such as muskrats (*Ondatra zibethica*) and waterfowl decline significantly. Others, such as marsh wrens (*Cistothorus palustris*) and least bitterns (*Ixobrychus exilis*), are displaced completely. Purple loosestrife provides food for few wildlife species (Thompson et al. 1987).

Other effects of exotic species may not be readily apparent. Therefore, we have developed the following list of ramifications of exotic pest plants to provide restorationists, land managers, researchers, nurseries, and others interested in exotic pest plants a background and understanding of these plants.

Implications of Exotic Pest Plants

1) **Changes species composition** — The introduction of an exotic herb species in a woodland may eliminate numerous other herb species over time (Cronk and Fuller 1995, Vitousek 1992, Iverson et al. 1991, Harty 1986, Vitousek 1986).

2) **Alters community structure** — The introduction of exotic species may lead to the development of a shrub layer and the elimination of the ground layer in woodland and forest communities (Cronk and Fuller 1995, Vitousek 1992, Hughes et al. 1991, Pimm 1986).

3) **Reduces species diversity of plant and animal communities** — The introduction of exotic species may lead to declines in numbers or elimination of plant, fish, insect, herptile, mammal, and other wildlife species, leading to a homogenizing or cosmopolitanization of the community due to domination by on or a few species (Cronk and Fuller 1995, Wagner 1993, Vitousek 1992, Soule' 1990, Thompson et al. 1987, Austin 1978).

4) **Alters nutrient cycling** — The introduction of exotic species may lead to an increase, decrease, or change in the cycling pathway of available nutrients to individual plants, a plant community, or an entire ecosystem (Dantonio and Vitousek 1992, Vitousek 1986).

5) **Alters regional microclimate** — The introduction of exotic species in a large area may lead to changes in a regional microclimate, which may favor the exotic species and be deleterious to more desirable native species (Vitousek 1986).

6) **Alters fire regime** — The introduction of exotic species may lead to changes in the natural fire regime, which will be favorable to the exotic species and deleterious to more desirable native species (Cronk and Fuller 1995, Dantonio and Vitousek 1992, Hughes et al. 1991, Vitousek 1986).

7) **Competition** — The introduction of exotic species may result in the exotic species competing with native species for light, nutrients, water, pollinators,

and seed bedding. Competition may ultimately result in a decrease or elimination of the native species from that area (Cronk and Fuller 1995, Loope 1992, Solecki 1993, Iverson et al. 1991, Auld and Tisdell 1986, Bowes et al. 1979).

8) **Diseases and parasites** — The introduction of exotic species may lead to the release of diseases and parasites to native plants. Even if these diseases do not infect more desirable native plant species, they may negatively affect the native wildlife populations (Ball et al. 1993, Daughtery 1993).

9) **Hybridization** — The introduction of exotic species may lead to the exchange of genetic material with native species and result in the loss of the local ecotype, sterile offspring, aggressive offspring which act as pests, offspring which are less productive, offspring which are less palatable to livestock or wildlife, weakened offspring which may be more susceptible to diseases, drought, or other environmental conditions (Harty 1993).

10) **Agricultural problems** — The introduction of exotic species may result in forage losses because of infestations of unpalatable or poisonous plants, high competition between crops and weeds, seed crop loss due to hybridization, and diseases spreading from infected exotic species (Cronk and Fuller 1995).

11) **Alters hydrology** — The introduction of exotic species may lead to accelerated wetland dehydration by increased evapo-transpiration (Vitousek 1992).

12) **Poisons animals** — The introduction of exotic species may result in decreased use of an area by livestock, wildlife, or humans because of severe rashes or wounds resulting from contact with a plant (Ball et al. 1993, Loope 1992, Austin 1978).

13) **Causes economic losses** — The introduction of exotic species has caused significant economic output to control these pests along roadsides, rangelands, croplands, waterways, timber production areas, golf courses, parks, natural areas, and private lands. Direct economic losses have occurred from exotic plants that cause death and illness to livestock (Ball et al. 1993, Auld and Tisdell 1986, Austin 1978).

14) **Creates aesthetic or recreational losses** — Monocultures of exotic pest plants may become an eyesore, e.g., thistles; clog waterways, thus preventing boating and fishing; and eliminate habitat, thus preventing hunting and trapping. If a plant is poisonous, it may eliminate hiking (Loope 1992, Soule' 1990, Harty 1986).

Conservation Ruminations

Harty (1986), in his treatise on exotic species, wrote: "In spite of mounting evidence of the ecological dangers associated with exotics, and the skyrocketing costs of controlling them, new species continue to be tested and promoted for the same ignorant reasons: 1) wildlife habitat plantings, 2) landscaping purposes, 3) wood and fiber production, and 4) soil conservation practices. An example is the promotion of sawtooth oak (*Quercus acutissima*) as an alternative wildlife food plant (Hopkins and Huntely 1979). Coblentz (1981) pointed out the lack of foresight and, more importantly, the lack of hindsight, in promoting sawtooth oak for mast production for wildlife because of its weedy characteristics. He also states, "Although the economic cost of controlling exotic introductions can be calculated, the ecological damage cannot be measured in dollars. For example, purple loosestrife invaded a 'premier calcareous fen' which the state of Illinois had purchased. It may be beyond controlling and the cost of this exotic species to the state is at least $379,000, the cost of purchase. The fen is irreplaceable."

Not all exotic species may be invasive pests. History, however, has shown that a species may not initially appear to be invasive because it may reproduce very little or not at all for many years. Eventually, however, it may adapt sufficiently to become naturalized and spread into the landscape as have Osage orange (*Maclura pomifera*), winged euonymus (*Euonymus alatus*), autumn olive (Harty 1986), and purple loosestrife.

CONCLUSIONS

Not all invasive exotic plants have all of the above implications. However, experience shows that a great many invasive species harbor more than a few of these characteristics. It is hoped that restorationists, land managers, ecologists, and others interested in controlling exotic pest plants (or, preserving native species, communities, and ecosystems) will find this list useful in management, planning, and politics.

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AN ASSESSMENT OF PRAIRIE RESTORATION AT TWO NATIONAL MONUMENTS

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ABSTRACT: One goal of the National Park Service, for park units in the prairie region, is to restore and maintain the native prairie vegetation to presettlement conditions. The objectives of this study were: 1) to compare the species composition of native prairie areas to areas undergoing restoration and 2) to evaluate the success of restoration methods. Species presence data were collected from prairies at Scotts Bluff National Monument and Effigy Mounds National Monument. Mean frequency of vegetation class data were analyzed using principal component analysis. The vegetation of the native areas sampled at Scotts Bluff National Monument were high in sedges and native cool-season grasses, characteristic of the mixed grass prairie of the region. Dominance of warm-season grasses on five restoration sites, uncharacteristic of the native prairie of the region, appears to be a result of an inappropriate and/or failed seeding. Analysis of data from Effigy Mounds National Monument separated formerly cultivated sites, dominated by exotic grasses and forbs, from previously grazed sites. Seeding and prescribed burning of formerly cultivated sites have decreased exotic grasses and increased warm-season grasses characteristic of the bluestem prairie. Although high in exotic grasses, the previously grazed sites contain grasses and forbs more characteristic of the native prairie of the region.

Key words: Scotts Bluff National Monument, Effigy Mounds National Monument, National Park Service, principal component analysis, mixed prairie, tallgrass prairie

INTRODUCTION

The ultimate goal of the National Park Service (NPS), for park units in the prairie region, is to restore the native prairie vegetation to presettlement conditions and to maintain it at that level. Various restoration methods have been used to achieve this goal depending on the current site condition, previous land use practices, potential vegetation, community type, and location.

The NPS, in planning additional restoration work at Scotts Bluff National Monument and Effigy Mounds National Monument, was interested in the level of success of their previous restoration methods at those sites. Therefore, the objectives of this research were: 1) to compare the species composition of native prairie areas to areas undergoing restoration and 2) to evaluate the success of these restoration methods.

SITE DESCRIPTIONS

Scotts Bluff National Monument

The predominant soil type at the Scotts Bluff National Monument study sites is a Mitchell silt loam [coarse-silty, mixed (calcareous), mesic Typic Ustorthent] formed in material that weathered from Brule siltstone and then transported and deposited to form short foot slopes or broad, nearly level, basinlike fans (SCS 1968). This is a deep, well-drained or moderately well- drained, immature soil that has a medium-textured layer beneath the surface layer.

The climate in extreme western Nebraska is semiarid continental. Average annual precipitation is 365 mm with an average growing season of 136 days (SCS 1968). The majority of precipitation occurs from April to June with lesser amounts from July to September. From October to March, precipitation generally occurs as snowfall.

Scotts Bluff National Monument lies in the central part of the High Plains within the northern mixed prairie. The northern mixed prairie is characterized by a plant community composed of both midgrasses and shortgrasses (Weaver and Albertson 1956). Küchler (1964) identified the grassland region of western Nebraska as a mosaic of grama-buffalograss (*Bouteloua-Buchloë*), grama-needlegrass-wheatgrass (*Bouteloua-Stipa-Agropyron*), wheatgrass- needlegrass (*Agropyron-Stipa*), and sandsage-bluestem prairie (*Artemisia-Andropogon*). Although the exact composition of these grassland communities prior to settlement is not known, the species composition of this region was probably dominated by a mixture of cool-season midgrasses and warm-season shortgrasses and grasslike species including western wheatgrass (*Agropyron smithii* Rydb.), threadleaf sedge (*Carex filifolia* Nutt.), needleandthread (*Stipa comata* Trin. & Rupr.), blue grama [*Bouteloua gracilis* (H.B.K.) Lag. *ex* Griffiths], and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] (Weaver and Albertson 1956, SCS 1968, Singh et al. 1983, Wendtland 1993). Important forbs include golden aster [*Chrysopsis villosa* (Pursh) Nutt.], plains sunflower (*Helianthus petiolaris* Nutt.), upright prairie coneflower [*Ratibida columinifera* (Nutt.) Woot. and Standl.], goldenrod (*Solidago* spp.), and scarlet globemallow [*Sphaeralcea coccinea* (Pursh) Rydb.]. Important shrubs include sand sagebrush (*Artemisia filifolia* Torr.), fringed sagebrush (*Artemisia frigida* Willd.), winter fat [*Ceratoides lanata* (Pursh) Howell], rubber rabbitbrush [*Chrysothamnus nauseosus* (Pall.) Britt.], and soapweed (*Yucca glauca* Nutt.).

Scotts Bluff National Monument is divided into 12 management units. Twenty-seven restoration areas have been identified within these units. Seven of these restoration areas and two native areas were chosen for study.

Restoration Site 2 (16 ha) was used for dry land wheat production prior to acquisition in 1979. This site was planted with a cover crop of grain sorghum [*Sorghum bicolor* (L.) Moench] in the spring of 1980. In fall 1980, it was seeded to sideoats grama, little bluestem [*Schizachyrium scoparium* (Michx.) Nash], blue grama, western wheatgrass, green needlegrass (*Stipa viridula* Trin.), Indian ricegrass [*Oryzopsis hymenoides* (R. and S.) Ricker], sand bluestem (*Andropogon hallii* Hack.), and upright prairie coneflower. A site evaluation in 1991 indicated that the dominant grass was little bluestem.

Restoration Site 3 (6.5 ha) was used for irrigated crops prior to acquisition in 1981. The site was planted to millet (*Panicum miliaceum* L.) in the spring of 1987. In spring 1988, it was disced and, again, planted to millet. In fall 1988, the site was mowed and planted to a mixture of western wheatgrass, blue grama, sideoats grama, buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], prairie sandreed [*Calamovilfa longifolia* (Hook.) Scribn.], little bluestem, and needleandthread. Site evaluations in 1990 and 1991 indicated that the dominant vegetation on the site was a mixture of annual exotic species with a few native grasses.

Restoration Site 4 (8 ha) was used for dry land farming prior to 1971. The area sustained a wildfire in 1980. The site's present condition indicates that it may have been seeded with a native mixture, but records of the seeding have not been located. A 1991 site evaluation indicated that a mixture of native and exotic vegetation with native vegetation dominating.

Restoration Site 5 (9.7 ha) was used for dry land farming prior to 1971. The site's present condition indicates that it may have been seeded with a native mixture. A 1991 site evaluation indicated that a mixture of native and exotic vegetation covered the site, with native species dominating.

Restoration Site 12 (9.7 ha) was used for dry land wheat production prior to 1974. In May of 1989, a wildfire burned the entire site. In the fall of 1989, old field edge berms were recontoured and seeded with the same mixture of grasses used in Restoration Site 3. The former berm area was dominated by kochia [*Kochia scoparia* (L.) Schrad.] and Russian thistle (*Salsola iberica* Sennen & Pau) in 1990. A site evaluation in 1991 revealed that the vegetation composition of most of the field consisted of a rubber rabbitbrush overstory and an understory of downy brome (*Bromus tectorum* L.) and red threeawn (*Aristida longiseta* Steud.). The western end of the field had good stands of sideoats grama and blue grama.

Restoration Site 13 (28 ha) was used for dry land wheat production prior to 1974. The site's present condition indicates that it may have been seeded, but records of the seeding cannot be located. A site evaluation in 1991 revealed that the site has two separate vegetation types. The northern one-half is virtually all non-native crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] and native western wheatgrass. The southern one-half is a mixture of native species along with a high percentage of downy brome and Russian thistle.

Restoration Site 15 (19.8 ha) was used for field crops prior to 1974. The field was planted with a cover crop of grain sorghum and seeded with an unknown native grass mixture sometime following the 1974 acquisition. A 1991 site evaluation indicated that the vegetation of the area was about 80% sideoats grama and 10% little bluestem.

About 16 ha of Native Range Site-North and an equal area of Native Range Site-South were selected for sampling. These areas, acquired with the initial establishment of the park in 1919, contain vegetation characteristic of the native mixed grass prairie of the region. No restoration is planned for these sites.

Effigy Mounds National Monument

Effigy Mounds National Monument (EFMO) is located in the "Driftless Area" or nonglaciated area of northeastern Iowa. The predominant soil type of the EFMO study sites is a Fayette silt loam (fine-silty, mixed, mesic Typic Hapluadalf) formed from loess in undulating to rolling uplands (SCS 1956, 1982). This is a well-drained, moderately fertile soil of uplands and stream benches.

The climate of northeastern Iowa is continental characterized by warm summers, cold winters, and moderate rainfall. Average annual precipitation is about 825 mm with an average growing season of 150 days (SCS 1956, 1982). The majority of precipitation occurs as rainfall between April and September. November to March precipitation generally occurs as snowfall.

This area features wooded bluffs and the floodplain along the Mississippi River. The monument lies in a transition zone between the prairie to the west and the hardwood forest to the east. Küchler (1964) identified the potential vegetation of this region as a mosaic of bluestem prairie (*Andropogon-Panicum-Sorghastrum*), oak-hickory forest (*Quercus-Carya*), and maple-basswood forest (*Acer-Tilia*). Blewett (1986) and Moore (1988), in a review of historical records and early survey records of the area, concluded that northeastern Iowa was a heavily forested region dominated by sugar maple (*Acer saccharum* Marsh.) and basswood (*Tilia americana* L.). The forested areas were interspersed with prairie openings along the ridge tops, and smaller prairie openings were found on south-facing bluff edges. These prairie areas would be classified as tallgrass prairie (Weaver and Clements 1938). Dominant grass species included big bluestem (*Andropogon gerardii* Vitman), switchgrass (*Panicum virgatum* L.), Indiangrass [*Sorghastrum nutans* (L.) Nash], and little bluestem. Important forbs included goldenrods, prairie coneflower [*Ratibida pinnata* (Vent.) Barnh.], sunflowers (*Helianthus* spp.), field pussy-toes (*Antennaria neglecta* Greene), blazing star (*Liatris punctata* Hook.), and white aster (*Aster ericoides* L.). Important shrubs include leadplant [*Amorpha canescens* (Nutt.) Pursh] and wild roses (*Rosa* spp.). These prairie openings were maintained during presettlement times by lightning-caused fires as well as by fires set by Native Americans.

Effigy Mounds National Monument is divided into two main units—the North Unit and the South Unit. The level uplands in both units were farmed until the 1940s and then allowed to revegetate naturally. A prairie remnant of about 10.5 ha occurs in the South Unit. The site objective for the eight prairie restoration units is to restore and maintain the native presettlement vegetation. Seven of these restoration areas and one native "goat prairie" area were chosen for study.

Restoration Sites A (3 ha), B (2.5 ha), and C-1 (3 ha) in the South Unit were probably seeded for hay and grazing prior to the establishment of the monument in 1949. They have not been seeded since acquisition. Eurasian grasses, such as smooth brome (*Bromus inermis* Leyss.) and bluegrasses (*Poa* spp.), are major components of the vegetation. Indiangrass is widespread, along with numerous prairie forbs. Woody vegetation has invaded along the forest edge and is also found scattered throughout the sites.

A native "goat prairie," Site (1 ha), is located in the South Unit, northeast of Site C-1. This native area contains vegetation characteristic of the native tallgrass prairie of the region, although woody vegetation has invaded from the surrounding forest. No restoration is planned for this site.

Restoration Sites D (2.2 ha) and F (9 ha) are in the North Unit. These sites had been in crop rotation for over 40 years prior to the establishment of the monument in 1949. They had been seeded for hay production at that time and have been idle since 1949. These areas are dominated by the exotics smooth brome, bluegrasses, and wild carrot (*Daucus carota* L.). Woody vegetation has invaded along the forest edge. Prescribed burns were conducted occasionally on the sites. They were seeded in the spring 1993 to a native seed mixture including the grasses big bluestem, sideoats grama, switchgrass, little bluestem, Indiangrass, and tall dropseed [*Sporobolus asper* (Michx.) Kunth] and 61 species of forbs and shrubs. Seeding was done with a broadcast seeder that was preceded by scarification using a pull-type harrow to prepare the seedbed.

Restoration Sites E (2.2 ha) and G (7 ha) are in the North Unit. These sites had a history similar to that of Restorations Sites D and F. They were seeded at the same time and with the same methods used on D and F, except tall dropseed was not included and slightly different forbs and seeding rates were used.

METHODS

Species presence data were collected at Scotts Bluff National Monument using a 0.2-m^2 rectangular quadrat. Random samples were taken at equal intensities throughout the sites, and the plant species rooted within the outline of the frame were recorded. Data were collected August 16 through 18, 1993 and 1994. The number of samples at each site varied between 100 and 200 and was determined by the size of the site. Species presence data were collected at Effigy Mounds National Monument using a 0.1-m^2 rectangular quadrat. Random samples were taken at equal intensities throughout the sites and the plant species rooted within the frame were recorded. Data were collected during August 10 through 12, 1993 and August 9 through 12, 1994. The number of samples, determined by the size of each site, varied from 50 to 120.

Species presence data for each site were converted to frequency of occurrence. The species were then assigned to one of eight vegetation classes. Classes at Scotts Bluff National Monument were native warm-season perennial grasses, native cool-season perennial grasses, exotic cool-season perennial grasses, annual grasses, perennial forbs, annual/biennial forbs, shrubs/succulents, and sedges. Vegetation classes for Effigy Mounds National Monument were native warm-season perennial grasses, native cool-season perennial grass/grasslike plants, exotic cool-season perennial grasses, native perennial forbs, native annual/biennial forbs, exotic perennial forbs, exotic annual/biennial forbs, and woody plants. Frequency of occurrence for each vegetation class within each site was then determined. The SAS Principal Component Analysis Procedure (Proc Princomp) (SAS 1990) was applied to the correlation matrix of the mean frequency of vegetation class data at each location.

RESULTS AND DISCUSSION

Scotts Bluff National Monument

Principal Component Analysis (PCA) for the vegetation class mean frequency of occurrence data yielded eight principal components. The eigenvalues indicate that the first three components accounted for more than 84% of the total variance. Vegetation classes and their eigenvectors for the first three principal components are shown in Table 1. The first axis of the PCA correlated most negatively with native warm-season perennial grasses and annual/biennial forbs and most positively with native cool-season perennial grasses and sedges. A gradient from a lower seral stage prairie, dominated by early successional annual/biennial forbs, to a higher seral stage prairie, dominated by cool-season grasses and sedges typical of the northern mixed prairie, is suggested. The second axis correlated most negatively with exotic cool-season perennial grasses and positively with perennial forbs, native warm-season perennial grasses, shrubs/succulents, and sedges, as supported by the negative and positive vector loadings respectively (Table 1). This axis also suggests a gradient from a lower to a higher seral stage prairie. The third axis had a strong positive correlation with annual grasses and forbs and a weak negative correlation with the remaining vegetation classes. This axis explains only 18.5% of the variation among the study sites. This, along with the weak negative correlations, make interpretation of PC3 difficult.

The position of the site locations in the first and second components and in the first and third components is plotted in Figures 1 and 2, respectively. Figure 1 revealed three groupings. These groupings indicate that the sites within each group are of similar vegetational composition. One group included the native sites, Native North (NN) and Native South (NS). These sites plotted the most positive of all sites on PC1, indicating areas high in native cool-season perennial grasses and sedges. The dominant native cool-season perennial grasses sampled on the native sites were western wheatgrass and needleandthread. The northern mixed prairie, described by Weaver and Albertson (1956), Küchler (1964), and Singh et al. (1983), is dominated by cool-season species, primarily western wheatgrass and needleandthread.

In addition, the mean frequency of occurrence of sedges in the Native North and Native South sites was 84.0 and 51.0%, respectively. Threadleaf sedge was the dominant sedge with a mean frequency of occurrence of 82.0 and 49.8% for the Native North and Native South sites, respectively. All other sites had 0% frequency of sedges, except Site 4 which had 0.5%. In the mixed prairie of the plains states, threadleaf sedge often ranks among the most important grasslike species (Weaver and Albertson 1956). It usually grows with blue grama, needleandthread, and a

Table 1. Eigenvectors resulting from principal component (PC) analysis on vegetation classes for Scotts Bluff National Monument.

Vegetation Class	Eigenvectors		
	PC1	PC2	PC3
Native warm-season perennial grasses	–.449	+.374	–.167
Native cool-season perennial grasses	+.547	–.105	–.068
Exotic cool-season perennial grasses	+.113	–.634	–.094
Annual grasses	+.120	–.244	+.712
Perennial forbs	+.122	+.409	+.584
Annual / biennial forbs	–.466	–.123	+.326
Shrubs / succulents	+.267	+.312	–.036
Sedges	+.412	+.330	–.054

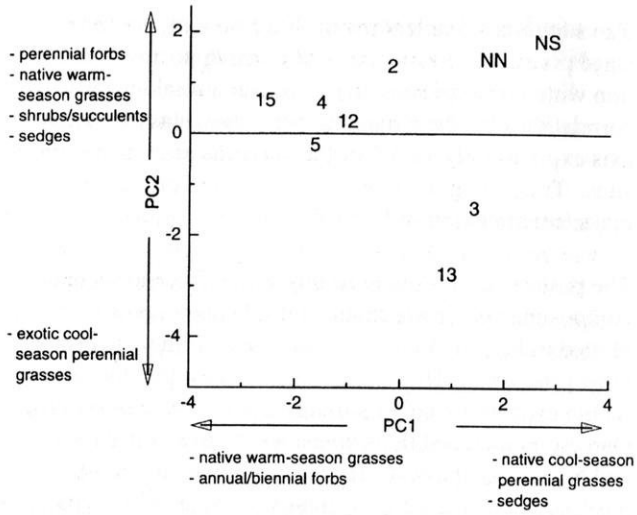

Figure 1. Position of study sites at Scotts Bluff National Monument

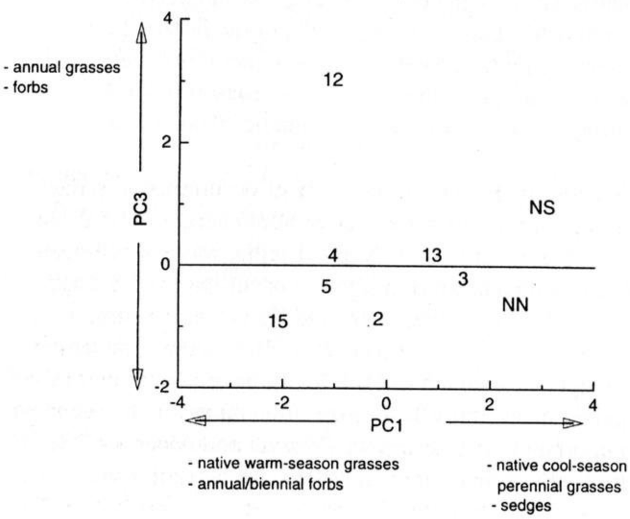

Figure 2. Position of study sites at Scotts Bluff National Monument

variety of other grasses but may form nearly pure stands on dry, sandy soil.

The native sites also plotted positively on PC2, indicating sites high in perennial forbs, native warm-season perennial grasses, sedges, and shrubs/succulents. These vegetation classes contribute nearly equally to the vegetational composition of these sites. The native areas contained the highest diversity of perennial forb species of all sites sampled. Scarlet globemallow, a long-lived perennial forb associated with the native mixed prairie, occurred with the greatest frequency in the native sites. It was the dominant perennial forb in both the Native North and Native South sites with a mean frequency of occurrence of 17.3 and 41.8%, respectively. In addition, these areas contained several perennial forb species which were not sampled in the restoration areas.

Blue grama was the most frequently sampled native warm-season perennial grass in these areas, with a mean frequency of occurrence of 22.3 and 28.0% for the Native North and Native South sites, respectively. This shortgrass is an important dominant in the mixed prairie (Weaver 1954) and occurred most frequently on the native areas. Judd and Jackson (1939) and Samuel and Hart (1994), in studies of succession in western Nebraska and Wyoming, found blue grama to occur more frequently in native compared to disturbed grasslands. Other native warm-season grasses sampled in these areas included sideoats grama, buffalograss, prairie sandreed, little bluestem, and sand dropseed [*Sporobolus cryptandrus* (Torr.) Gray]. No exotic cool-season perennial grasses were sampled in these areas, further supporting the positive loading of these sites in relation to PC2, as well as the interpretation of this axis.

A second grouping, including Restoration Sites 3 and 13, were sites formerly under cultivation and were acquired in 1981 and 1974, respectively (Figure 1). Restoration Sites 3 and 13 plotted positively on PC1, indicating areas high in native cool-season perennial grasses. The dominant native cool-season perennial grass sampled was western wheatgrass. Other frequently sampled species included needleandthread and green needlegrass. In addition, Restoration Sites 3 and 13 had the lowest frequency of native warm-season perennial grasses of all sites sampled. Sites 3 and 13 plotted negatively on PC2, indicating a high percentage of exotic cool-season perennial grasses. These sites also had the lowest frequency of perennial forbs of the sites sampled. This further explains the negative loading of these sites in relation to PC2, as well as the interpretation of this axis. Perennial forbs sampled in Site 3 included Platte thistle (*Cirsium canescens* Nutt.), cutleaf ironplant [*Haplopappus spinulosus* (Pursh) DC.], ground cherry (*Physalis* spp.), scarlet globemallow, and prairie coneflower. Perennial forbs sampled in Site 13 included gold aster, western wallflower [*Erysimum asperum* (Nutt.) DC.], false boneset (*Kuhnia eupatorioides* L.), skeletonweed [*Lygodesmia juncea* (Pursh) Hook.], ground cherry, upright prairie coneflower, and scarlet globemallow.

A third grouping contains Restoration Sites 2, 4, 5, 12, and 15 (Figure 1). These areas were under cultivation prior to becoming part of the monument and were planted to a commercial seed mixture following acquisition. These areas plotted negatively on PC1, indicating areas high in native warm-season perennial grasses and annual/biennial forbs and low in native cool-season perennial grasses and sedges. The most frequently occurring warm-season grasses on these sites were sideoats grama and little bluestem. Although these grasses are a component of the mixed grass prairie of the region, they are not typically the dominant species (Weaver and Albertson 1956, Küchler 1964, Singh et al. 1983). These restoration sites had the highest mean frequency of annual/biennial forbs of all sites sampled, with the exception of Site 2.

The mean frequency of annual/biennial forbs on Site 2 was more similar to the native sites, causing it to plot the most positive of these sites on PC1. The most frequently sampled annual/biennial forbs in these sites were exotic species, predominately Russian thistle and yellow sweetclover [*Melilotus officinalis* (L.) Pall.]. Native annual/biennial forbs sampled or observed at these sites included common ragweed (*Ambrosia artemisiifolia* L.), annual spurge (*Euphorbia* sp.), and common sunflower (*Helianthus annuus* L.).

Annual and biennial forbs generally appear early in succession but are much less common in later stages. Allen and Knight (1984) and Samuel and Hart (1994) found the annuals kochia and Russian thistle and the biennial sweetclover to be among the species that dominated the vegetation in the first few years after disturbance in Wyoming. The negative plotting of these sites on PC1 also indicates areas low in native cool-season perennial grasses and sedges. There were no sedges sampled in these areas, with the exception of Site 4, where sedges had a mean frequency of occurrence of 0.5%. The three most frequently sampled native cool-season perennial grasses were western wheatgrass, needleandthread, and green needlegrass. The dominant cool-season perennial grasses in Site 2 were western wheatgrass followed by green needlegrass and needleandthread. The dominant cool-season species in Sites 4 and 5 were needleandthread and western wheat-grass and the dominant species sampled in Site 12 was needleandthread. The only native cool-season perennial grass sampled in Site 15 was western wheatgrass with a mean frequency of occurrence of 2.4%.

Sites 2, 4, 5, 12, and 15 plotted positively on PC2, indicating these areas were high in perennial forbs and shrubs/succulents and low in exotic cool-season perennial grasses. Site 12 had the highest frequency of perennial forbs of all sites sampled. The dominant perennial forbs in this site were western ragweed (*Ambrosia psilostachya* DC.) and skeletonweed. Tolstead (1941) observed western ragweed to be among the first perennial species to enter abandoned fields in the mixed prairie of South Dakota. Sites 2, 4, 5, and 15 had a higher frequency of occurrence of perennial forbs than Sites 3 and 13, but lower than that of the native sites, further explaining their location in relation to PC2. These sites contained a variety of perennial forbs including scarlet globemallow, false boneset, skeletonweed, western ragweed, and asters (*Aster* spp.). The vegetation of Site 15 consisted almost entirely of native warm-season perennial grasses and annual/biennial forbs, causing it to plot the most negative of all sites on PC1. Site 2 had the second highest frequency of occurrence of shrubs/succulents of all sites sampled. This further explains its positive loading on PC2 and supports the interpretation of this axis. The dominant shrub in this area was fringed sagebrush but also included rubber rabbitbrush and winter fat.

The strong positive loading of Site 12 on PC3 (Figure 2) and the negative loading of Site 12 on PC1 (Figure 1) suggest a low seral stage prairie community high in annual grasses, forbs, and warm-season perennial grasses. This site had the highest mean frequency of occurrence of annual grasses and forbs of all sites sampled. The dominant annual grasses in this site were the exotics downy brome and Japanese brome (*Bromus japonicus* Thunb. *ex* Murr.). Both are serious competitors to the native vegetation on medium and fine textured soils (Gartner et al. 1978).

In addition, Site 12 contained several weedy forb species such as lambsquarters, common sunflower, kochia, sweetclover, Russian thistle, skeletonweed, and field bindweed (*Convolvulus arvensis* L.). Annual/biennial forbs occurred the most frequently in this site, particularly in 1993. The dominant species were the exotics sweetclover, a biennial, and the annuals Russian thistle and kochia. Allen and Knight (1984) concluded that the presence of exotic weeds resulted in a significant reduction in cover of both native annuals and perennials.

Although Sites 3 and 13 were high in exotic cool-season grasses. The species composition of these areas more closely resembles the native mixed grass community than does the vegetation of the other restoration sites (Figure 2). Species sampled in Sites 3 and 13 included the native warm-season grasses red threeawn, sideoats grama, blue grama, buffalograss, sand dropseed, and the cool-season western wheatgrass. The other restoration sites, with the exception of Site 12, were dominated by little bluestem and sideoats grama which, although components of the mixed grass prairie, are not typically the dominant species. The composition of Restoration Sites 2, 4, 5, 12, and 15 suggests that successional change, inappropriate seeding, and/or failed seeding have contributed to a species composition not characteristic of the native mixed grass prairie. In addition, threadleaf sedge, a prominent component of the Native areas, was absent or occurred at a very low frequency in all of the restoration sites sampled.

Effigy Mounds National Monument

Principal Component Analysis for the vegetation class mean frequency of occurrence data yielded eight principal components. The eigenvalues indicate that the first three components accounted for 78% of the total variance. The remaining components explained 22% of the variation among the sites, providing little additional information. Vegetation classes and their eigenvectors are shown in Table 2. The first axis of the PCA correlated most positively with forbs and exotic cool-season perennial grasses and most negatively with native warm-season perennial grasses, woody plants, and native cool-season perennial grass/grasslike plants. This axis correlates with a gradient from an earlier successional prairie community, induced by plowing and dominated by exotic grasses and forbs, to a later successional prairie dominated by warm-season perennial grasses and woody plants. The second axis correlated most positively with native perennial forbs, native warm-season perennial grasses, and cool-season perennial grass/grasslike plants and most negatively with woody plants (Table 2). This axis correlates with a gradient from an earlier successional prairie community dominated by forbs and grasses to a later successional community dominated by woody plants.

The third axis explains less than 15% of the variation among the study sites, making it difficult to interpret. It correlated most positively with native cool-season perennial grass/grasslike plants and native annual/biennial forbs and most negatively with native warm-season perennial grasses and exotic cool-season perennial grasses.

The positions of the sites of the first and second components and the first and third components are plotted in Figures 3 and 4, respectively. The general pattern confirms interpretations based only on the eigenvectors of dominant vegetation classes. Locations with large positive scores on PC1 are low seral stage prairie sites dominated by exotic cool-season perennial grasses and exotic perennial and annual/biennial forbs while those with large negative scores are higher seral stage prairie sites dominated by native warm- and cool-season perennial grasses and woody plants.

Principal component 1 appears to separate the North Unit sites (D, E, F, G), which were formerly cultivated, from the South Unit sites (A, B, C-1), which were previously grazed, and the native "goat prairie" site (GP). Myster and Pickett (1988), in an investigation of old field

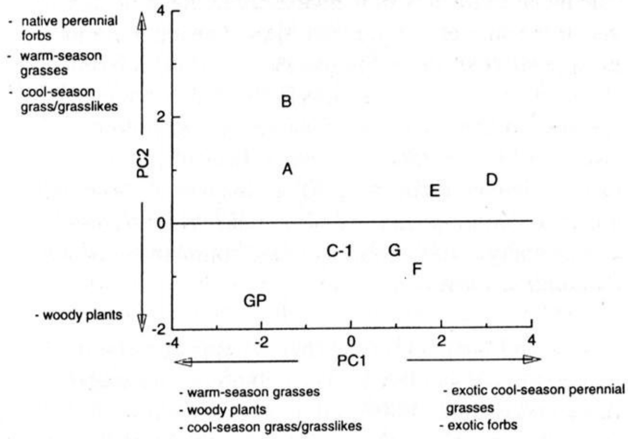

Figure 3. Position of study sites at Effigy Mounds National Monument

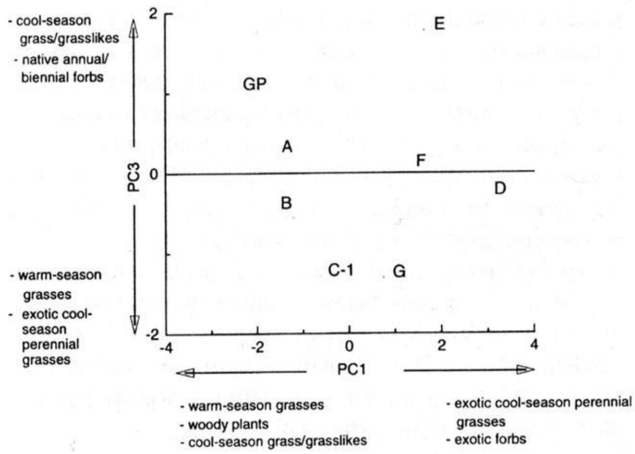

Figure 4. Position of study sites at Effigy Mounds National

Table 2. Eigenvectors resulting from principal component (PC) analysis on vegetation classes for Effigy Mounds National Monument.

Vegetation Class	Eigenvectors		
	PC1	PC2	PC3
Native warm-season perennial grasses	– .368	+ .474	– .330
Native cool-season perennial grass / grasslike	– .220	+ .416	+ .559
Exotic cool-season perennial grasses	+ .467	– .140	– .253
Native perennial forbs	+ .237	+ .567	– .197
Native annual / biennial forbs	– .184	– .057	+ .538
Exotic perennial forbs	+ .495	+ .082	+ .191
Exotic annual / biennial forbs	+ .462	+ .078	+ .385
Woody plants	– .221	– .495	+ .030

succession in New Jersey, concluded that old fields that shared initial conditions at the time of abandonment showed similar succession patterns.

Restoration Sites D and E plotted the most positive of all sites on PC1, indicating areas high in exotic cool-season perennial grasses and exotic forbs and low in native warm- and cool-season perennial grasses and woody plants. These areas had the highest frequency of exotic perennial, as well as annual/biennial forbs of the sites sampled. The dominant exotic cool-season perennial grasses were smooth brome and bluegrasses but also included quackgrass [Agro*pyron repens* (L.) Beauv.] and redtop (*Agrostis stolonifera* L.). The dominant exotic forbs were wild carrot and perennial clovers (*Trifolium* spp). Restoration Sites D and E plotted positively on PC2, suggesting areas low in woody plants. This is supported by the data which indicate these areas had the lowest mean frequency of occurrence of woody plants of all sites sampled. This is also consistent with the interpretation of PC1.

Restoration Sites F and G also plotted positively on PC1 (Figure 3), indicating areas high in exotic perennial cool-season grasses and exotic forbs and low in native warm- and cool-season perennial grasses and woody plants. The dominant exotic cool-season grasses in these sites were smooth brome and bluegrasses but also included redtop and quackgrass. The most frequently sampled exotic forbs were wild carrot and field bindweed.

Restoration Sites D, E, F, and G had similar compositions of native forb species. The most frequently sampled native annual/biennial forbs were common ragweed and hog peanut [*Amphicarpaea bracteata* (L.) Fern]. Other species included tall bellflower (*Campanula americana* L.) and showy partridge pea (*Cassia chamaecrista* L.). These species were not sampled in the South Unit sites. The most frequently sampled perennial forbs were whorled milkweed (*Asclepias verticillata* L.), asters (*Aster* spp.), wild bergamot (*Monarda fistulosa* L.), black-eyed Susan (*Rudbeckia hirta* L.), rigid goldenrod (*Solidago rigida* L.), and other goldenrod species.

The species composition of Site G, although high in exotic grasses and forbs, suggests that it is in the best condition of the formerly cultivated sites. This site had the highest frequency of warm-season grasses of the sites sampled in the North Unit. The dominant warm-season grasses sampled were big bluestem and little bluestem but also included Indiangrass. Although prominent on this site, exotic forbs occurred at a lower frequency than on Sites D, E, and F of the North Unit.

The South Unit sites (A, B, C-1) all had 0% frequency of exotic annual/biennial forbs and a low percent frequency of exotic perennial forbs. Exotic cool-season grasses, although not as prominent as in the North Unit sites, were still an important component of Sites A, B, and, C-1. Restoration Sites A and B plotted negatively on PC1, indicating areas higher in native warm- and cool-season perennial grasses and woody plants and lower in exotic cool-season perennial grasses and exotic forbs than the study sites of the North Unit (Figure 3). These sites had the highest mean frequency of native warm-season grasses of all sites sampled. The dominant species was Indiangrass.

Restoration Site C-1 plotted negatively, but close to zero, on PC1, indicating an area intermediate between the South Unit Sites A, B, and GP and the North Unit sites (Figure 3). Site C-1 had the highest frequency of exotic cool-season grasses of the South Unit sites. This site also had the highest frequency of woody plants, with the exception of the "goat prairie" site. Thomson (1943) found that shrubby and woody plants such as blackberry (*Rubus allegheniensis* Porter) and smooth sumac (*Rhus glabra* L.) became more pronounced in fields abandoned for more than 22 years in central Wisconsin. The forest had encroached considerably by the time the field had been abandoned for 37 years, and a decrease in the prairie species was observed.

Site C-1 also had a lower percentage of warm-season grasses than Sites A and B, which further contributed to its position in relation to PC1 and PC2. This site's negative loading on PC3 reflects its similar frequency of warm-season grasses and exotic cool-season grasses with Site G. Although the percentage of warm-season grasses in these sites was similar, the dominant species sampled was Indiangrass in Site C-1 and big bluestem in Site G.

The native "goat prairie" site (GP) plotted the most negative of all sites on PC1 (Figure 3), indicating an area low in exotic cool-season perennial grasses and exotic forbs and high in native warm-season perennial grasses, woody plants, and native cool-season perennial grasses. This site had the lowest percent frequency of exotic cool-season perennial grasses of all sites sampled and 0% frequency of exotic forbs. The dominant warm-season grass sampled in the "goat prairie" was big bluestem with a mean frequency of occurrence of 27%. Others sampled were little bluestem and Indiangrass. Marks (1942) described the "goat prairies" of the Driftless Region of southwest Wisconsin as upland prairies with herb layers dominated by big bluestem, little bluestem, and Indiangrass growing in clumps along with sideoats grama and hairy grama (*Bouteloua hirsuta* Lag.). The native "goat prairie" site plotted the most negative of all sites on PC2, indicating an area high in woody plants. This site had the highest frequency of occurrence of woody plants of all sites sampled. The "goat prairie" site plotted positively on PC3 (Figure 4), suggesting an area high in native cool-season perennial grass/grasslike plants.

Native cool-season perennial grass/grasslike species sampled in this site included poverty oatgrass [*Danthonia spicata* (L.) Beauv. *ex* R. & S.], *Dichanthelium* spp. and sedges.

Cool-season perennial grass/grasslike species occurred at a greater frequency in the "goat prairie" than the native warm-season grass species characteristic of the bluestem prairie of the region described by Tolstead (1938) and Marks (1942). In addition, the high frequency of woody plants suggests that this area is succeeding toward a forest community. Native perennial forbs sampled on the "goat prairie" site included pussytoes (*Antennaria* spp.), azure aster (*Aster oolentangiensis* Ridd.), tickclovers (*Desmodium* spp.), round-head lespedeza (*Lespedeza capitata* L.), Virginia mountain mint (*Pycnanthemum virginianum* Dur. & Jackson *ex* Robins. & Fern.), rigid goldenrod, and finger coreopsis (*Coreopsis palmata* Nutt.). Similar species were observed by Tolstead (1938) and Marks (1942) on prairie areas of Iowa and southwest Wisconsin.

CONCLUSIONS AND RECOMMENDATIONS

The desired result of prairie restoration at Scotts Bluff National Monument (SCBL) and Effigy Mounds National Monument (EFMO) is an advanced successional stage, approximating the presettlement vegetation. Establishment of late successional species should reduce time required to reach this stage of vegetation. The comparison of the species composition of native prairie areas to areas undergoing restoration allowed for an evaluation of these areas in relation to the desired vegetation, as well as an evaluation of the success of restoration methods.

It can be concluded that past land use, grazing versus cultivation in this study, affects successional processes and rate of succession toward the desired vegetation type. Intense and long-continued cultivation delays the recovery of native vegetation by removing native perennial grasses, reducing the seed bank in the soil, and modifying the soil. Less intense cultivation or grazing followed by abandonment may leave viable rhizomes and crowns which will hasten the recovery of the area. Also, cultivation contributes to an unstable community which allows for the entry of exotic or other unwanted species.

The restoration areas sampled at SCBL were all formerly under cultivation and acquired from 1971 to 1981. The native areas sampled were dominated by cool-season grasses and threadleaf sedge along with numerous forbs and shrubs characteristic of the northern mixed prairie; whereas Restoration Sites 2, 4, 5, 12, and 15 were dominated by such native warm-season grasses as little bluestem and sideoats grama. These warm-season grasses are minor components of the northern mixed prairie, not typically the dominant species. It appears that this dominance resulted from an inappropriate seed mixture and/or a failed seeding.

The absence of threadleaf sedge in the restoration areas was another difference noted between these areas and the native areas. Establishing this sedge in the restoration areas will be a key factor in directing succession toward the surrounding native vegetation.

The seed mixture for future restoration purposes should be adjusted to include more of the characteristic cool-season species such as western wheatgrass and needleandthread. The establishment of threadleaf sedge may be possible by incorporating plugs of this species, taken from nearby native areas, into the restoration areas. Those restoration areas adjacent to native areas may benefit from natural recruitment of grasses as well as forbs and shrubs. Restoration areas not adjacent to native areas may benefit from a seed mix containing forb species in addition to the grasses.

The role played by cultivation and the subsequent invasion of exotic species in determining successional processes and the rate of succession are clearly visible in the North Unit sites of EFMO. Exotic grasses and forbs, which inhibit the establishment of native species, dominate these areas. Long-lived species that reproduce, spread, and/or retard succession, such as smooth brome and Kentucky bluegrass, must be removed or controlled if these sites are to succeed rapidly toward a species composition consistent with the goals of the park. Based on information collected from this study, as well as data collected by monument staff, prescribed burning treatments and native seeding at EFMO appear to have contributed to a decrease in exotic perennial grasses and exotic forbs and an increase in native warm-season grasses. An increase in species diversity was noted in the North Unit sites that was attributed to the seeding of native species. Continued periodic burning will help control the exotic cool-season grasses, promote the growth of the native warm-season grasses, and aid in the control of invading woody species.

Although exotic perennial grasses were found to be an important component in the South Unit sites, native prairie forbs and warm-season grasses typical of the bluestem prairie were prominent. These areas will benefit from continued periodic burning to inhibit the growth of exotic cool-season grasses, promote the native warm-season grasses, and control the invasion of woody species from the surrounding forest.

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RESTORATION OF A PRAIRIE PLANT COMMUNITY: HELP FOR A THREATENED SPECIES.

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ABSTRACT: The U.S. Fish and Wildlife Service (Service) in cooperation with the Washington State Department of Natural Resources (DNR) has designed and implemented a restoration project to benefit golden paintbrush (*Castilleja levisecta*) and the prairie habitat where it is extant. Golden paintbrush was formally proposed for listing as a threatened species by the Service. Native prairies of western Washington are rapidly declining due to urban development, agriculture, resource utilization, and the encroachment of native and non-native vegetation. The primary objective of this restoration project was to preclude the continued loss of habitat that supports golden paintbrush. The project is being conducted at the Rocky Prairie Natural Area Preserve, a site administered by the Washington DNR. Douglas fir (*Pseudotsuga menziesii*) and Scot's broom (*Cytisus scoparius*),which have invaded the prairies were removed. The harvesting of large, open-grown Douglas fir results in a circular area of bare ground where the trees used to be. In order to reduce colonization of these bare areas by non-native, invasive shrubs and grasses, the native Idaho fescue (*Festuca idahoensis*) and forbs including woolly sunflower (*Eriophyllum lanatum*), cinquefoil (*Potentilla gracilis*), cut-leaved microseris (*Microseris laciniata*), sickle-keeled lupine (*Lupinus albicaulis*), and showy fleabane (*Erigeron speciosus*) were planted. High-quality native grasslands of western Washington will continue to be threatened by development, conversion, and tree and shrub invasion. As prairies disappear, so will the species dependent upon them. Lessons learned from this prairie restoration project will be applied to future projects to enhance and maintain the original structure, composition, and function of native prairies.

Key words: golden paintbrush, native prairies, Natural Area Preserve, Washington

INTRODUCTION

The U.S. Fish and Wildlife Service (Service) has a shared responsibility with a variety of federal and state agencies, Native American tribes, and private organizations for the conservation of fish, wildlife, and plants and their habitats. A cooperative effort between the Service's Endangered Species Program and the Washington Department of Natural Resource's Natural Heritage Program (WNHP) has been implemented to restore native grasslands and improve the habitat of a proposed threatened species, golden paintbrush (*Castilleja levisecta* Greenman). This is the first effort of this type in western Washington to specifically restore prairie habitat and a proposed threatened plant. The primary objective of this project is to remove encroaching trees, revegetate the cleared areas with native grasses and forbs, and allow for the potential expansion of the golden paintbrush population.

Located in the lowlands of the Puget Trough of Washington State, prairies are a conspicuous feature of the western Washington landscape (Franklin and Dyrness 1973, Ugolini and Schlichte 1973, Kruckeberg 1991, Clampitt 1993). The lowland grasslands of this region were formed approximately 12,000 years ago by the deposition of outwash materials from the retreating Vashon Glacier and by subsequent erosion and the action of rivers. Coarse gravels deposited in the Puget Trough by the retreat of the glacier allowed prairies to develop in this conifer-dominated landscape (Thomas and Carey 1996). Evidence suggests that prairies became established during a time of warmer and perhaps drier climate, which reached its optimum roughly 10,000 to 4000 years before present, during the Hypsithermal period (Ugolini and Schlichte 1973). The term "prairie" was applied to these treeless grasslands by European settlers in the mid-1800s and continues to be used today. The settlement of the region by Europeans, however, brought on changes (land clearing and fire suppression) that promoted the encroachment of woody shrubs and trees into prairies.

Prairies and grassland habitats of western Washington and Oregon are being diminished rapidly by urban development, agriculture, resource utilization, and the encroachment of native and non-native vegetation (Gamon 1995). Historically, western Washington prairies covered over 200,000 acres. Today, these prairies cover less than 20,000 acres (Crawford and Hall 1997).

Description of the Study Area

The restoration project was conducted at Rocky Prairie Natural Area Preserve, south of Olympia, in Thurston County, Washington. Rocky Prairie was established as a preserve for the native Idaho fescue/Puget balsamroot (*Festuca idahoensis/Balsamorhiza deltoidea*) and to protect the proposed threatened golden paintbrush. Ten disjunct populations of this plant now exist, with Rocky Prairie supporting the largest population (Gamon 1995). Rocky Prairie is distinct from other grasslands that support golden paintbrush because it features Mima mounds and larger swales and rises (Washburn 1988). Soils are derived from glacial till and drift and are well drained. The soils are classified as the Spanaway series.

Rocky Prairie is dominated by grasses and forbs, including Idaho fescue or red fescue (*Festuca rubra*). Non-native, weedy grass species including velvet-grass (*Holcus lanatus*), orchard grass (*Dactylis glomerata*), and colonial bentgrass (*Agrostis tenuis*) also occur at this site, as most prairies have been degraded by past disturbances. In the absence of fire, the prairies have been colonized by Douglas fir, the native shrub Nootka rose (*Rosa nutkana*), and the aggressive, non-native Scot's broom. When these species encroach upon the prairies, native grasses and forbs are displaced, the prairies are degraded and ultimately replaced by Douglas-fir forests. Without management action, the prairie habitat of golden paintbrush will continue to decline.

Status of the Threatened Species

The rare plant, golden paintbrush is a perennial forb in the figwort (Scrophulariaceae) family. It is intolerant of shade and requires open growing conditions. It was historically more common on prairies and has been reported from 30 sites in Oregon, Washington, and British Columbia since its discovery in 1875. Golden paintbrush is now restricted to ten populations. One population is located on mainland western Washington, seven on islands in the Puget Trough of Washington ,and two on islands off the southeastern coast of Vancouver Island, Canada. The species was last observed in Oregon more than 50 years ago. Exhaustive efforts have failed to relocate this species in Oregon, and it is presumed to be extirpated there. As a result of the reduction in the number of populations and the continued threat of habitat loss, golden paintbrush was classified as endangered by the state of Washington in 1984. Golden paintbrush was formally proposed for listing as threatened in May 1994. A moratorium on listing from April 1995 to April 1996, enacted by the 104th Congress, held up any further action on the species. A final determination to list this plant as a threatened species was published in the Federal Register on June 11, 1997 (FR 31740).

METHODS

We proposed a project to remove trees from Rocky Prairie and to replant the exposed soil with native grass and forb species. Management activities at the Rocky Prairie Natural Area involved marking and harvesting Douglas firs from discrete portions of the prairie and revegetating the exposed, bare ground with native forbs and Idaho fescue seedlings. Douglas firs were marked to identify the trees to be harvested and to indicate the direction they would be felled, in order to lessen the impact to the prairie plants and soils. Tree harvesting, whole-tree removal, piling and raking of limbs and needle litter, and prescribed burning took place during January and February of 1996, when the golden paintbrush plants were dormant. Douglas firs were harvested from about seven acres of the prairie. Trees were removed from the site by helicopter and placed on a landing site off the preserve.

During the summer of 1995, the seeds of several native species were collected from Rocky Prairie to be propagated and replanted onto the site. Species included Idaho fescue, California oat-grass (*Danthonia californica*), woolly sunflower, sickle-keeled lupine, showy fleabane, cinquefoil, cut-leaved microseris, and field woodrush (*Luzula campestris*). Approximately 35,000 container-grown plugs of Idaho fescue were propagated from seed at the IFA Nursery in Nisqually, Washington. Seeds from the forbs were propagated by high school students at Cascades High School in Everett, Washington. Approximately 30,000 Idaho fescue seedlings were planted in mid-March of 1996 by staff from the Washington DNR, the authors, and volunteers. The success of the planted Idaho fescue was measured in late May 1996.

Mortality sampling was accomplished on roughly 35% of the area from which trees were harvested. Sampling was stratified by location within Rocky Prairie Natural Area Preserve. Plots were randomly selected within each location, using the stump from the harvested tree as the plot center. Sample plots were 3 m in radius.

Surveys to assess the amount of invasion by non-native plants onto the bare soil were conducted during early summer 1996. Weeding by hand to remove invasive, non-native plants was accomplished during mid-summer of 1996.

RESULTS

Results from the project represent only a glimpse of the possible outcome that may occur at this site in the future. Early results are mostly positive, however, some results emphasize the need to reevaluate how certain aspects of this project were accomplished. Monitoring will indicate how effective the prescription was at meeting the project objective and may require modifying the methods during the second phase of this project.

Mortality of planted Idaho fescue seedlings was less than 10%. Success of the planted forbs was generally less than Idaho fescue, but mortality was highly variable. Planted cut-leaved microseris declined by approximately 80%, having the greatest mortality of any species planted. Cinquefoil mortality was 50%, while about 15% of the wooly sunflower seedlings died. Other species showed little mortality, including the California oat-grass, showy fleabane, and field woodrush, each with about 10% mortality.

Invasive, non-native species quickly became established in the bare soil where trees had been harvested and the Idaho fescue and forbs had been planted. The Idaho fescue and the forbs, however, had not completely occupied these sites and the invasive species were able to germinate and compete with the native species for space on these recently exposed sites. The five, most abundant, non-native species that invaded the site included wood groundsel (*Senecio sylvaticus*), bull thistle (*Cirsium vulgare*), hairy cats-ear (*Hypochaeris radicata*), common velvetgrass (*Holcus lanatus*), and colonial bentgrass. Hand weeding removed roughly 50% of the invasive, non-native plants, although, it is expected that these plants will continue to invade the area from nearby pastures and other recently disturbed lands that tend to harbor these species.

DISCUSSION

Restorations of prairies require the manual and mechanical removal of invasive plants (grasses, shrubs, and trees) in addition to active management to restore ecosystem processes such as fire. Historically, fire was vital to the maintenance of prairies (Agee 1993, Kruckeberg 1991) and was used by Native Americans to increase the production of edible plant foods (Norton 1979), such as the bulbs of common camas (*Camassia quamash*), to improve forage production for deer, and possibly to herd deer for hunting. Repeated burns probably will be required to maintain native grassland conditions (J. Agee, pers. comm. 1996). The practice of burning the prairies was all but eliminated when Europeans came onto the scene in the mid-1800s.

The response of golden paintbrush to fire is unknown. Experience by The Nature Conservancy and Washington Department of Natural Resources at Rocky Prairie indicates there will be an initial reduction in the golden paintbrush population but that the species rebounds after several years. Management activities, such as prescribed burning, should help to restore, enhance, and maintain prairie habitat in the future. In a region dominated by coniferous forests, prairies provide a unique habitat to rare plant and animal species, but can only be maintained through management activities.

The succession of Douglas fir onto prairies threatens golden paintbrush and other native species by shading and competing for the limited resources available for plant growth on these glacial outwash prairies. Prescribed burning of prairies reduces the competition and shade by Douglas fir. When Douglas fir invades and establishes onto a prairie, it develops into an open-grown, individual tree with large branches that provide heavy shade. Upon reaching maturity, the trees produce heavy seed crops and dense stands of young Douglas firs radiate from the original, parent trees that occupied the site. Because Douglas fir produces heavy shade, the native prairie vegetation beneath the trees disappears. A heavy accumulation of needle litter develops beneath each tree and no forbs or grasses can grow under these conditions. However, when the Douglas firs are harvested and removed, seeds of a variety of native and non-native plants that have been stored in the soil for decades are able to flourish in this cleared, full-sunlight environment. In addition to Douglas fir encroachment, the greatest threat to the native prairie vegetation is the germination and growth of non-native species like Scot's broom. Scot's broom is a nitrogen-fixing, woody shrub that grows vigorously in open, bare-soil conditions.

Timing this project to revegetate the bare ground with native forbs and grass seedlings is crucial to its success. It is important to revegetate the bare ground with local, native seedlings as quickly as possible after the trees have been harvested to preclude invasion by new tree seedlings or Scot's broom. Native seeds and seedlings should be the best adapted vegetation for restoration and will likely have the greatest potential for survival and growth. The relatively high survival of the planted Idaho fescue and forbs during the first season after trees were harvested may be due to the late rains that occurred during the spring of 1996.

Monitoring this project will help assess how successful our cooperative efforts have been. Monitoring the success of the restoration activities will be required to indicate if these efforts have improved the conditions for golden paintbrush populations over the long term. The jury is still out on the Rocky Prairie restoration project. Monitoring occurred soon after tree harvesting and planting of the grass and forb seedlings were completed. At the time of initial monitoring, survival of planted grasses and forbs was generally high. Although, from casual observations during this past summer, it appears that mortality increased for all the planted species.

Rocky Prairie supports the largest population of golden paintbrush and, therefore, is critical for the long-term viability of this species. If golden paintbrush and the associated native prairie plants revegetate the areas formerly occupied by Douglas fir, then we can judge this project a success.

Pressure on western Washington prairie habitats from development, gravel extraction, agriculture, encroachment of non-native plants, and the succession of prairies to forest will continue. Habitat conservation and management have become important components in maintaining the health and diversity of species (Wentworth 1994). Botanists, plant ecologists, and conservation groups like The Nature Conservancy view prairies as a priority habitat and will continue to seek methods to restore these habitats to their original structure, composition, and function. This poses a difficult task, but the return on this investment to restore prairie habitat and the golden paintbrush should be positive.

CONCLUSIONS

The restoration activities at Rocky Prairie have, for the most part, been successful. The long-term response of the prairie ecosystem to management activities can be assessed with more certainty several years after the project was originally implemented. Additional restoration of the site was accomplished during the winter, 1997, when five acres of encroaching Douglas firs were harvested and removed from the site. During the fall of 1997, four .5-ha (2 ha total) experimental plots were burned. These activities have made more exposed, bare soil areas available for native species recovery, and an invasion by non-native grasses and forbs. A second planting of approximately 10,000 Idaho fescue plugs and smaller lots of five species of forbs were planted during late fall 1997.

The success of the planted Idaho fescue and forbs, and the expansion of the naturally occurring golden paintbrush population will continue to be monitored. The planted grasses and forbs have taken well; individual seedlings have expanded to cover the majority of the exposed bare surfaces. All of the planted grasses and forbs have matured and now flower and produce their own seeds to continue to fill in any small gaps that exist. Restoration of this native prairie has also created a favorable site for wind-born seeds of non-native, invasive species to move onto and occupy. Hand weeding of the five most abundant non-native species (see early results section) has been a high priority for volunteer efforts at the site. The influx of non-native plants has slowed since trees were first harvested in 1996, however, hand-weeding of the non-native plants remains a challenge.

The removal of mature trees and the experimental burns created areas of bare soil that made a favorable site for planting Idaho fescue and associated prairie forbs. These management actions shifted the vegetation to an early stage of secondary succession. Harvesting trees removed shade from the site, reduced competition, and restored natural ecosystem processes (fire) that had been missing for at least 50 years. The reintroduction of fire perpetuated early successional vegetation stages by inhibiting the reproduction of invasive woody species such as Douglas fir and Scot's broom. In the absence of fire or management, prairies in the Pacific Northwest succeed toward conifer-dominated forests. Removing competing vegetation and restoring natural processes made the site more suitable for native grasses and forbs. The low height of the planted species has enabled the threatened golden paintbrush to expand into newly created habitat. Restoration activities at Rocky Prairie are just one part of the restoration required to maintain and enhance the prairie ecosystems of western Washington. Additional work will be required to maintain the native prairie landscape. The site will serve as one of 15 protected sites (5 are presently established) that will be relied upon to contribute to the recovery of the threatened golden paintbrush.

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THE IMPORTANCE OF CATTLE IN CONSERVATION OF DRY PRAIRIE IN WISCONSIN

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ABSTRACT: Among Wisconsin prairie managers, cattle have been taboo. Yet many prairie plants and animals were found on some dry prairie pastures in the course of research during 1993–1996 on the rare prairie plant *Onosmodium molle*. This research also looked at the land use on *O. molle* sites and other taxa found on them. The importance of cattle to *O. molle* had been suspected, but the importance of cattle to other rare prairie species was a surprise that forces the reconsideration of how we define, and how we defend, our vanishing dry prairies.

Key words: *Onosmodium molle*, dry prairie, Wisconsin Department of Natural Resources

INTRODUCTION

Aldo Leopold (1933) wrote that cattle could be used, together with other tools often associated with the destruction of native communities, to manage and restore these ecosystems. John Curtis (1959) wrote that grazing destroys mesic and wet prairies quickly, but that dry prairies can endure grazing somewhat better because the alien taxa most invasive in grasslands generally cannot succeed in such dry conditions. Despite the tremendous influence the body of work left to us by these two people, none of the conservation agencies in Wisconsin use grazing as a tool to manage prairies.

In the course of Masters research focused on *Onosmodium molle* A. Michaux (Boraginaceae) in Wisconsin, many prairie taxa, some rare enough to be listed as endangered or threatened by the Wisconsin Department of Natural Resources (WDNR), were discovered in the same pastures where *O. molle* is successful (Williams 1996). These rare prairie taxa include plants, birds, insects, and probably other less well-studied fauna. The importance of cattle to *O. molle* had been suspected, but the importance of cattle to other rare prairie species was a surprise that forces the reconsideration of how we define and defend our vanishing dry prairies.

METHODS

Onosmodium molle was sought using data from historic collections, from WDNR files, from the literature, from knowledgeable people, and by actively searching for it across the landscape. A census was made of O. molle plants wherever found, except for the four largest populations, so the area in which they grew could be circumscribed and better understood. If a population spread over an area that included different sets of land- use practices, such as a pasture and its adjacent roadside, these were studied as two separate sites, two different land-use units.

Once the *O. molle* plants on a site were located, all the other plant species growing there were recorded. Plants at sites where *O. molle* was suspected to occur also were recorded. Areas where it was too damp or shady were not included in the inventory. The result is a site flora for each *O. molle* site listing those plants that grew where *O. molle* grew or might as well be growing, based on where it actually grew on that site. Sites were visited repeatedly to make each site flora as complete as possible. These data are tabulated in a single, 28-page appendix in Williams (1996).

RESULTS

Onosmodium molle was found on 59 sites in Wisconsin. There were 71 species found on more than 50% of these sites. This is a list of species, including many alien plants, that grow in dry prairie pastures, and this is the most appropriate description of *O. molle* habitat in Wisconsin. Rare plants on these sites included *Lespedeza leptostachya* (endangered, on 7% of *O. molle* sites), *Asclepias lanuginosa* (threatened, 3%), *Cacalia plantaginea* (threatened, 22%), *Cirsium hillii* (threatened, 19%), *Echinacea pallida* (threatened, 3%), *Parthenium integrifolium* (threatened, 5%), *Carex richardsonii* (special concern, 8%), and *Pediomelum esculentum* (19%). Grassland birds present in these prairie pastures include loggerhead shrike (*Lanius ludovicianus*, endangered), Bell's vireo (*Vireo belii*, threatened), upland sandpiper (*Bartramia longicauda*), northern bobwhite (*Colinus virginianus*), horned lark (*Eremophila alpestris*), eastern kingbird (*Tyrannus tyrannus*), brown thrasher (*Toxostoma rufum*), eastern and western meadowlarks (*Sturnella magna* and *Sturnella neglecta*), bobolink (*Dolichonyx orizivorus*), dickcissel (*Spiza americana*), nesting common nighthawk (*Chordeiles minor*), wild turkey (*Meleagris gallopavo*), and vesper (*Pooecetes gramineus*), field (*Spizella pusilla*), savannah (*Passerculus sandwichensis*), grasshopper (*Ammodramus savannarum*), and clay-colored (*Spizella pallida*) sparrows. Grassland insects probably include many species we don't yet know much about, but regal fritillary (endangered) is present in several *O. molle* pastures. This grazed prairie habitat is, almost without exception, the only habitat in which regal fritillaries are now found in Wisconsin.

DISCUSSION

The percentages given above may not seem as significant as they actually are. For example, *Lespedeza leptostachya* is currently known from about 16 sites in Wisconsin, 4 of which are sites where *O. molle* also occurs. This means 25% of the current *L. leptostachya* sites also support *O. molle*. Another example is *Asclepias lanuginosa*, which is currently known from about eight sites in Wisconsin, two of which are sites where *O. molle* also occurs. This means 25% of the current *A. lanuginosa* sites also support *O. molle*.

One other *A. lanuginosa* site is in a pasture where *O. molle* doesn't grow. This can be said of others of these rare prairie taxa as well—rare species were found in pastures where *O. molle* was sought but not found. These similar sites are not reflected in the percentages above. Many prairie pastures that don't support *O. molle* are also of tremendous conservation value.

Bell's vireo is listed as threatened in Wisconsin, yet in this research, this bird was frequently encountered in these brushy, dry prairie pastures where *O. molle* was found or sought. If WDNR looked at these pastures, Bell's vireo might not be deemed sufficiently rare to warrant threatened status. This is true of *Cirsium hillii* as well. The presence of cows has apparently caused conservationists to look elsewhere for prairie taxa, because of the unwarranted reputation of cows in the destruction of prairie. While cows have certainly destroyed many prairies, it is not the cows themselves that cause this destruction; rather it is the grazing regime imposed on the land by farmers that is to blame. That it is easy to destroy prairie with cattle has led to the faulty conclusion that cattle invariably destroy prairie.

These dry pastures are generally large, old pastures that have not been tilled in the past because they are rocky. Mowing is not done in these pastures, or it is partial and occasional. Herbicides are not used in these pastures, except occasionally as spot application, and neither is fire. This may be especially important in terms of prairie insect conservation. In the past, our management of Wisconsin prairies has depended on fire and we are only now beginning to realize that this may be devastating to prairie insect diversity. Though we may have saved some plants by using fire to manage prairies, we may have irreparably damaged these prairies by eliminating many species of insects.

These pastures offer a new and spacious, fire-free, species-rich arena in which to practice a less fire-dependent form of prairie conservation. For conservationists to ignore pastures because they imagine cattle have destroyed the native flora and fauna is to miss a huge opportunity to affect prairie conservation in Wisconsin today and in the future.

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INVENTORY OF *ONOSMODIUM MOLLE* IN WISCONSIN: HISTORIC STATUS, PRESENT STATUS AND FUTURE PROSPECTS

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ABSTRACT: *Onosmodium molle* was sought after in Wisconsin using information from herbaria, Wisconsin Department of Natural Resources (WDNR) files, the literature, knowledgeable people, and by searching the landscape. During 1993–1996, land use on *O. molle* sites and the flora present on them were studied. This rare prairie and savanna plant is less widely distributed in Wisconsin today than it was earlier. Several factors conspire against *O. molle* in Wisconsin: the rising human population with its attendant development, the suppression of fire on the landscape, the reduction of pasture and altered pasture practices, increased use of herbicides to manage vegetation, our cultural bias toward trees and away from grassland, the bureaucratization of conservation by governments, and Wisconsin conservationists' bias against grazing as a management tool.

Key words: Onosmodium molle, land-use practices, pasture reduction, conservation bias

INTRODUCTION

This paper is the core of the author's Master's research, which culminated in a thesis of about 400 pages, including 19 appendices of tabular data. This report focuses on the results of the thesis research and supporting data can be found in the thesis (Williams 1996).

Onosmodium molle A. Michaux (*sensu* Das 1965, Gleason and Cronquist 1991) (Boraginaceae) is a rare prairie and savanna plant in Wisconsin, listed by WDNR as a species of special concern. The plant was sought by several means and the sites where it grows, or once grew, were studied. From the 59 current sites where it was found naturally growing in Wisconsin, generalizations of habitat and land-use practices pertinent to its conservation are made.

METHODS

Onosmodium molle is widely distributed around our midcontinent, ranging from Montreal south to northern Georgia, west to central Texas and northeastern New Mexico, and north up the eastern slope of the Rocky Mountains to Calgary, Alberta. Various authors including Fernald (1950) have characterized its habitat as dry calcareous, sandy, rocky or gravelly prairies, banks, glades and open woods. The key elements are well-drained calcareous soils in full or partial sun. Because the plant is most common in our midcontinental grassland, we can infer the important influences of mammalian grazing and fire.

Five avenues of research were followed in pursuit of *O. molle* in Wisconsin. The most productive avenue was to review specimens of *O. molle* collected in the state. Help was requested of 315 herbaria, of which 135 provided data that allowed mapping the entire range of *O. molle* by county. Where possible, label data were used to pinpoint where the collections had been made and to provide names of associated plants and habitat generalizations. Some collectors were contacted in an effort to get further information.

Because the species is listed as being of special concern by WDNR, a file on this species exists at the Bureau of Endangered Resources (BER). The file yielded some new information. BER also has files on sites that might harbor *O. molle*, given the search image that was taking shape, and these were reviewed and the sites investigated.

From botanical literature, habitat information was collected across the entire range of *O. molle*, with special attention paid to Wisconsin (Cochrane 1976). Regional floras within the state proved interesting but of little use.

Knowledgeable people were approached by mail, telephone, and through announcements in newsletters. This produced nothing in southeastern Wisconsin, but proved very rewarding in southwestern Wisconsin, where the plant probably has always been more common.

In searching for *O. molle* in the field, special attention was paid to the vicinity of known sites, and the search benefited from the participation of over a dozen volunteers, many of whom also assisted in data collection from *O. molle* sites. Thousands of miles were driven around the southern half of the state, and seemingly thousands were also spent on foot searching for the plant and studying the sites where it was found.

Once a site was discovered, land-use practices, *O. molle* itself, and other plants present were studied. Land use was of greatest interest. Some information could be surmised from the landscape itself, for example, this site was a pasture. But much information could only be obtained from the people who had managed the land. In the case of this pasture, we sought to know: what livestock had grazed here, how heavily were they stocked, when during the year (i.e., intermittently or continuously); were herbicides used (which ones and how were they applied); was mowing used (when and with what frequency and pattern); was fire used (when and with what frequency); how long had this site been a pasture; had alien grasses been oversown; and had the site ever been tilled?

Except for the four largest populations, a census was made of *O. molle* plants wherever found so the area in which they grew could be circumscribed and better understood. Plants were counted in various stem number categories so recruitment into the population by young plants could be roughly measured and correlated with land use. If a population spread over an area that included different sets of land-use practices, such as a pasture and its adjacent roadside, these were studied as two separate sites, two different land-use units.

Once the *O. molle* plants on a site were located, all other plant species growing in that land-use unit were recorded. Also, plants were recorded in sites where *O. molle* was not found but could grow. Areas where it was too damp or shady were not included in the inventory. The result is a site flora for each *O. molle* site listing those plants that grew where *O. molle* grew or might as well be growing, based on where it actually grew on that site. Sites were visited repeatedly to make each site flora as complete as possible. These data are tabulated in a single, 28-page appendix in Williams (1996).

RESULTS

Although historic collections of *O. molle* have been made in Brown, Outagamie, Ozaukee, Milwaukee, Rock, Waushara, and Juneau counties in eastern and central Wisconsin, it is now unknown in this region, except for one site beside a railroad track in Brown County. Today, *O. molle* is essentially restricted to the bluffs along the Mississippi River and the pastures below these bluffs, to current and retired pastures, and along roadsides and utility rights-of-way in southwestern Wisconsin. Historic collections were made near the Mississippi River in LaCrosse, Vernon, and Crawford counties. Current natural populations, however, were not found in these counties. *Onosmodium molle* was found on a total of 59 sites in Grant (22 sites), Pierce (13), Iowa (12), Dane (6), Green (3), Lafayette (1), Buffalo (1), and Brown (1) counties. Surely there are a few *O. molle* colonies that escaped detection in this study.

Excluding three species that grew with *O. molle* only because they had been planted near it, 494 taxa were included in these site floras. There were 71 species found on more than 50% of the *O. molle* sites. This list of species includes many alien plants that grow in dry prairie pastures, which is the most appropriate habitat description of *O. molle* in Wisconsin.

A diversity of rare plants grew with *O. molle*, including several listed as endangered, threatened, or of special concern by WDNR. Rare prairie animals such as grassland birds and regal fritillary butterflies were repeatedly discovered in the same places where *O. molle* grew.

The fungus *Rhizoctonia* sp. appeared to be the primary killer of individual *O. molle* plants, but land-use practices are the key to the future of *O. molle* in Wisconsin.

DISCUSSION

Though 59 *O. molle* sites were found, some of which support relatively large populations, *O. molle* is at risk in Wisconsin due to changing land-use practices. From the site descriptions in Williams (1996) can be winnowed several factors that conspire against *O. molle* in Wisconsin. Each is briefly discussed below.

The Rising Human Population with its Attendant Development

Since 1840, southern Wisconsin has been transformed largely by farming. Through both tillage and grazing, most of this savanna and prairie landscape has been converted for agricultural purposes. More recently, urban sprawl has become a serious problem affecting *O. molle* almost everywhere it occurs or occurred.

The Suppression of Fire on the Landscape

Over this same period fire has been vigorously suppressed, so much so that use of fire by conservationists today often requires an educational effort to overcome what has become a cultural fear of outdoor fire. This suppression of fire has occurred over a period when woody vegetation has increased and the incidence of *O. molle* has decreased, especially along the Mississippi River bluffs. Limited data from this study suggest that fire may benefit *O. molle* by removing thatch, resulting in sunnier, warmer, and drier conditions at the soil surface (Daubenmire 1968). This may foster growth by established plants and may allow greater recruitment of seedlings.

The Reduction of Pasture and Altered Pasture Practices

Cattle and horses generally do not eat *O. molle*, and by eating the nearby plants, they lessen the competition for resources faced by each *O. molle* plant. Light grazing by cattle and horses benefits *O. molle*. Grazing also reduces the thatch load and the standing biomass which observations in this study suggest inhibit recruitment of young *O. molle* plants, probably by casting too much shade. Open pasture is where young plants are apparent, although they may be present under heavier vegetative cover where they are simply less likely to be found.

Mowing is done in parts of some pastures in this study to control thistles, to improve the quality of the forage, and to reduce the incidence of pinkeye in cattle. Based on observations made in pastures and along road rights-of-way, *O. molle* cannot persist where mowing occurs. Though individual plants may briefly persist where mowed once a year, reproduction occurs only where plants are not mowed during the growing season.

Herbicides are applied to some pastures in this study. Where herbicides are spot applied to weeds, such as thistles or multiflora rose, *O. molle* can persist. But where entire pastures are sprayed with herbicides to kill broadleaved plants and to foster dominance by grasses, *O. molle* probably cannot persist.

The largest *O. molle* population in the state is in Pierce County, where grazing was discontinued. Though this population is huge and is momentarily secure in a large open area, other local populations are being overgrown by woody vegetation, a process that will almost certainly happen on this large site as well. The farm harboring the second largest *O. molle* population in Wisconsin was sold in 1996 to a developer who intends to put in a golf course and houses, with the approval of the local town government that seeks growth. WDNR is now discussing these plans relative to the endangered regal fritillary and threatened Bell's vireo that live here, but land use here is changing. The third largest *O. molle* population in Wisconsin was a retired pasture when purchased by The Nature Conservancy (TNC). Despite the influence of grazing in producing a site worthy of their conservation efforts, TNC conceived of the grazing as a negative influence and has not included grazing in its management of this site. The suppression of grazing here has led to a top-heavy *O. molle* population that crashed in 1996. Though *O. molle* will persist on this site for some time, it probably will not recover its former abundance without grazing.

The Increased Use of Herbicides to Manage Vegetation

The increased use of herbicides threatens native vegetation generally, including *O. molle*. In pastures and along utility and road rights-of-way, death of *O. molle* plants was observed after herbicides had been sprayed, although in some cases injury did not result in mortality after a single spraying. With repeated spraying over years, it seems less and less likely that *O. molle* will persist in such places.

Our Cultural Bias Toward Trees and Away From Grassland

In the course of this research, we met many people who were unaware that prairie exists in Wisconsin. The concept of natural communities, including various types of prairie, apparently is not widely known in Wisconsin.

Government agencies foster planting of trees and brush in grassy vegetation in several ways. WDNR operates tree nurseries, making young trees available cheaply to those who want to plant them. There are now pine plantations all over southern Wisconsin, and it's not uncommon to see these state-sponsored young pines planted in rocky prairies. The cultural value expressed here is the belief that we must make the land produce something that "improves" our property. Many who plant pines imagine they are improving the environment when, in fact, they are destroying what the land would naturally produce. In this way, biologically diverse, native grassland, which could continue for centuries given appropriate management, is replaced by sterile, alien plantation woodlands designed to be cut after a single generation.

Destruction of prairie in this way can profit the landowner through federal subsidy of the cost of the planted trees and through a state tax break on the acreage planted to trees through the Managed Forest Tax Law, if more than a certain minimum area is involved. The cultural value exposed by this practice is the belief that production of trees is worthy of societal support. Unfortunately, there is no consideration of what may be destroyed in pursuit of this worthy goal.

Many people turn to WDNR or their county forester for advice on how to improve their land for wildlife. Traditionally, such advice included making wildlife plantings, tilling the ground and planting a mix of alien, herbaceous species with the expectation that wildlife would do the harvesting. Another traditional bit of advice is to plant trees and brush in order to provide food, cover, and edge. Often these plants are provided cheaply by the state nurseries and often they are not native to the area in which they are planted. WDNR and its corollary agencies in other states have a long history of introducing alien fauna and flora. Until recently, the term wildlife really meant game animals and, to a lesser degree, songbirds, but the trend is to include all native taxa. In the past, there was little emphasis on native species and the protection or restoration of native communities. But in the minds of an increasing number of people, pheasants and brown trout are not wildlife, whereas prairie plants and animals, including *O. molle* and its fauna are wildlife. The traditional influence of WDNR and county foresters has worked against *O. molle*, and to the extent the old ideas still operate, the advice and actions of these government agencies continue to threaten it.

Bureaucratization of Conservation by Governments

Government functions by dividing its diverse responsibilities across agencies. This is inevitable. One problem is that the right hand of government often doesn't know what the left hand is doing and so they work at cross purposes. One example of this problem in the context of conservation was presented above: in favoring the planting of trees and brush for wildlife generally, the agencies do great damage to prairie ecosystems. Of all the situations into which trees and brush may be introduced in southern Wisconsin, those in which the most damage can be done are savannas and prairies, remnants of the presettlement vegetation. Conservation would be better served by protecting these remnants, but to those given the responsibility to oversee tree planting, tree planting tends to become the greatest goal.

Another example of this is the WDNR Bureau of Fisheries trying to improve water quality in streams and to foster native trout fisheries wherever possible. This seems like a worthy goal until one looks at the damage done to prairies through the exclusion of cattle and cessation of grazing likely to follow on the heels of stream fencing in many current pastures. The prairie flora and fauna remaining in such pastures warrant primary consideration and should not become victims of trout hatcheries.

A third example is the concern of the federal Natural Resources Conservation Service (NRCS) over soil erosion. In the one *O. molle* pasture in which I know the NRCS has tried to intervene to lessen soil erosion, the majority of the native flora, including most of the *O. molle* population, grow on the slope of concern. The flat areas are largely devoid of native plants. It is on the drier slope, where the conservation service wants to intervene, that the prairie taxa successfully compete against the alien pasture grasses. Here again, soil conservation is a worthy goal, but it must take into consideration the needs of existing prairie vegetation when it attempts to mitigate erosion.

Wisconsin Conservationists' Bias Against Grazing as a Management Tool

Aldo Leopold (1933), a figure so large in the history of conservation in Wisconsin that he is nearly a deity, wrote that cattle could be used with other tools often associated with the destruction of native communities to manage and restore them. John Curtis (1959), a local giant in the field of plant ecology and the description of presettlement vegetation in Wisconsin, wrote that grazing destroys mesic and wet prairies quickly, but that dry prairies can endure grazing somewhat better because the alien taxa most invasive in grassland generally cannot succeed in such dry conditions. Despite the importance of the bodies of work left to us by these two people, and despite the perhaps disproportionate attention they get from conservationists seeking the right way to accomplish almost anything in Wisconsin, none of the conservation agencies here employ grazing as a management tool in prairies. WDNR grazes in conjunction with prairie chicken management on land that is not prairie, but otherwise does not use grazing. The Nature Conservancy grazes nowhere in Wisconsin. Neither, to my knowledge, does any other not-for-profit organization. In Wisconsin, grazing is apparently taboo among conservationists.

CONCLUSIONS

Onosmodium molle persists and can be successful in dry rocky pastures that contain moderate numbers of cattle and/or horses throughout the growing season, or in pastures that experience intermittent grazing. By documenting the flora and, to a lesser extent, the fauna in these pastures, this study has shown that many species considered prairie species, and some of these of sufficient rarity to be listed as threatened or endangered by the state of Wisconsin, live in these pastures. For Wisconsin conservationists to ignore pastures because they imagine cattle have destroyed the native flora and fauna is to miss a great opportunity both to conserve *O. molle* and to affect prairie conservation in Wisconsin today, and in the future.

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