2002

Monitoring of prairie bushclover (Lespedeza leptostachya) in south-central Iowa

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MONITORING OF PRAIRIE BUSHCLOVER (*LESPEDEZA LEPTOSTACHYA*) IN SOUTH-CENTRAL IOWA

An Abstract of a Thesis

Submitted

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

Paul J. Bockenstedt

University of Northern Iowa

May 2002

ABSTRACT

Prairie bushclover *Lespedeza leptostachya* is listed as threatened by both the U.S. Fish and Wildlife Service and the State of Iowa. Found within the tallgrass prairie region only in four midwestern states, prairie bushclover is considered a midwestern endemic. The federal recovery plan includes the goal to stabilize populations through proper management techniques and long-term management plans.

In 1989, three permanent plots were established for long-term monitoring at Madison Prairie in Clarke County, Iowa to examine population trends under the influences of fire and grazing. Fifty prairie bushclover plants were randomly selected within the three plots and square meter sampling quadrats were centered on these plants. The plots were initially sampled 1989-91, and were sampled for this study during the 1993-1995 growing seasons and the data was combined for analysis.

Plants were observed to commonly become dormant for a one year interval and then reappear the following year. However, reappearance of individual plants after more than one year of dormancy was rare. Across treatments there was a presumed overall loss of 46% (21 of 46) loss of monitored individuals from 1989 to 1995, suggesting this plant is a relatively short-lived perennial. No pattern of influence of fire on *Lespedeza leptostachya* could be discerned due to conflicting results. No statistically significant effect of cattle grazing on *Lespedeza leptostachya* was observed, although under light moderate grazing, it was not selected by cattle and appeared to be benefited by removal of competitive associates, creation of community gaps and shifts in community composition. *Lespedeza leptostachya* apparently does not fare well in competitive situations as

treatments with the most stable prairie community showed the highest rates of *L. leptostachya* dormancy and death. There were indications of it being an opportunistic plant that benefits from a limited amount of disturbance.

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This Study by: Paul J. Bockenstedt

Entitled: Monitoring of Prairie Bushclover *Lespedeza leptostachya* in South-central Iowa

has been approved as meeting the thesis requirement for the

Degree of Master of Arts

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DEDICATION

To my wife, Cathy, daughter Lara, and son Daniel. You give my heart wings. ♡

ACKNOWLEDGMENTS

I wish to gratefully acknowledge the following people and organizations for their help:

- My wife, Cathy, daughter Lara, and son Daniel for their limitless patience and encouragement
- Dr. Daryl Smith, a mentor and friend, for support, wisdom, and guidance, and for sharing his heartfelt enthusiasm about prairie and other natural areas
- Dr. Paul Christiansen and Dr. Laura Jackson for manuscript review and shared wisdom
- Scott Zager for assistance in data interpretation and questions of plant ecology
- The Flaherty Family, owners and stewards of Madison Prairie
- Clarke County Conservation Board, for early assistance in landowner coordination
- My employer Bonestroo, Rosene, Anderlik, & Associates, Inc., for flexibility in my work schedule to complete this manuscript

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INTRODUCTION

Review of Literature

Life History of Prairie Bushclover

Prairie bushclover (*Lespedeza leptostachya*) is listed as a threatened species by both the U.S. Fish & Wildlife Service and the State of Iowa. Found only in the tallgrass prairie region in four Midwestern states, prairie bushclover is considered a Midwestern endemic (Sather 1990). The historical and present distribution of the plant indicates it is most abundant in a core area of approximately 38,000 km^2 (Figure 1). The core area lies on the glacial drift of the Des Moines Lobe of the Wisconsin glacier in southern Minnesota and north-central Iowa. Individuals in core populations number in the hundreds to thousands while peripheral populations number in the tens to hundreds (Smith et al. 1988). As of 2001, approximately 80 populations of *L. leptostachya* were known in 36 counties in northern Illinois, southern and western Wisconsin, southern Minnesota, and Iowa.

A member of the legume family, prairie bushclover is generally between 22 and 95 cm in height. The trifoliate leaves have leaflets that are 2 to 4 cm long and 2 to 8 mm wide, with appressed pubescence above and silky hairs below (Fox 1945). Plants are erect with stems numbering from one to five, although most have one or two stems. Two types of flowers may occur on a single plant, chasmogamous (open, potentially outcrossing), and cleistogamous (closed, obligately self-pollinating). Both types may be produced on a single plant, or an individual may produce only cleistogamous flowers.

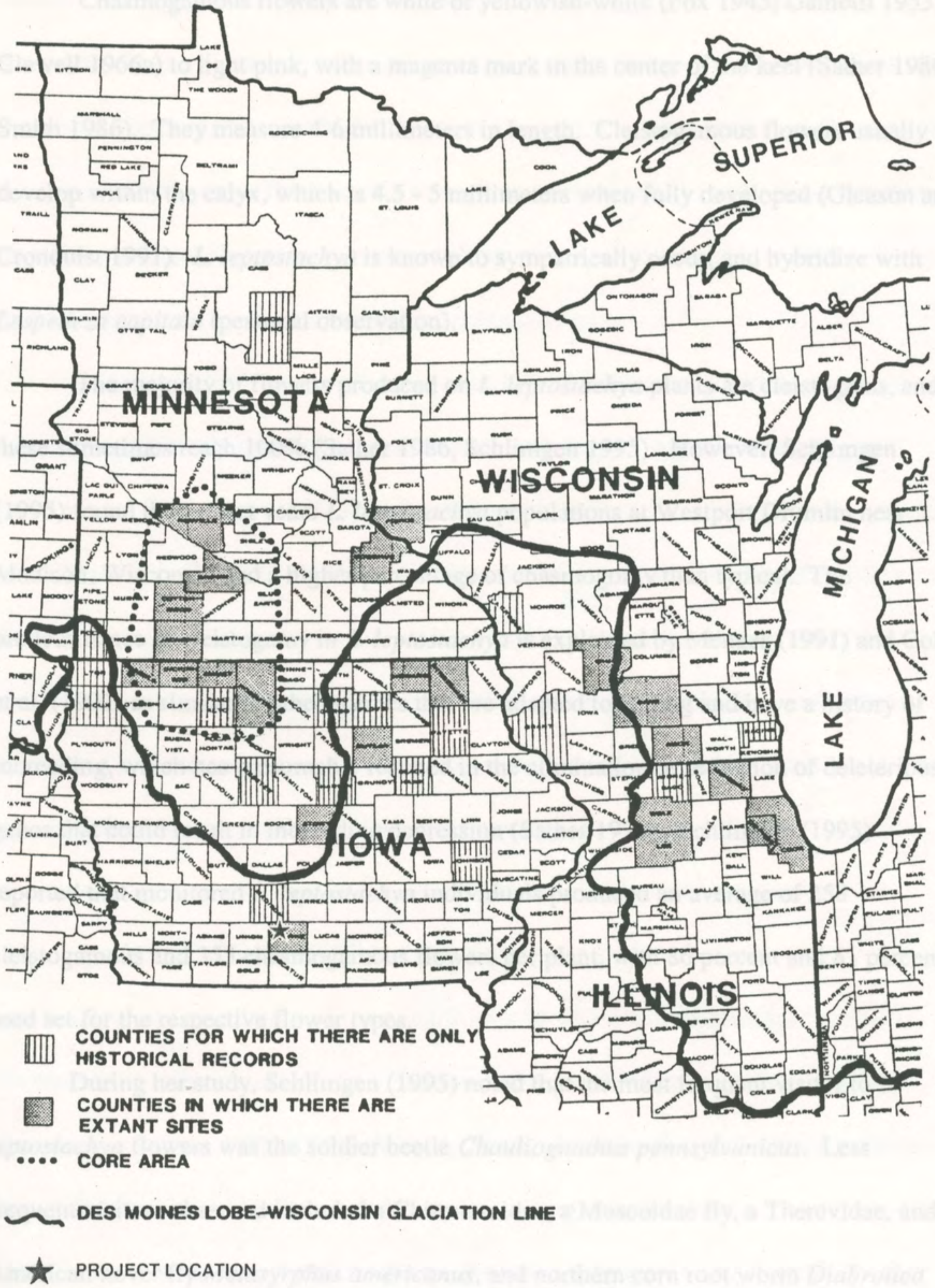


Figure 1: 1988 and historical distribution of *Lespedeza leptostachya* (adapted from USFWS, 1988)

Chasmogamous flowers are white or yellowish-white (Fox 1945; Gambill 1953; Clewell 1966a) to light pink, with a magenta mark in the center of the keel (Sather 1986, Smith 1986). They measure 4-6 millimeters in length. Cleistogamous flowers usually develop within the calyx, which is 4.5 - 5 millimeters when fully developed (Gleason and Cronquist 1991). *L. leptostachya* is known to sympatrically occur, and hybridize with *Lespedeza capitata* (personal observation).

The majority of flowers produced on *L. leptostachya* plants are cleistogams, and these sometimes reach 100% (Sather 1986, Schlimgen 1995). However, Schlimgen (1995) found that in wet years *L. leptostachya* populations at Westport Drumlin near Madison, Wisconsin had a higher percentage of chasmogomy than typical. The predominance of cleistogamy in *L. leptostachya* is explained by Menges (1991) and Cole et al. (1992) as similar to other species that are adapted to selfing and have a history of inbreeding, which has presumably resulted in the elimination or reduction of deleterious genes that could result in inbreeding depression (Sather 1992). Schlimgen (1995) reported that monitored *L. leptostachya* individuals produced an average of 258 cleistogamous and 355 chasmogamous flowers per plant, with 86 percent and 81 percent seed set for the respective flower types.

During her study, Schlimgen (1995) noted that the most frequent visitor to *L. leptostachya* flowers was the soldier beetle *Chauliognathus pennsylvanicus*. Less frequent visitors observed included a Chironomidae, a Muscoidae fly, a Therevidae, and American hover fly *Metasyrphus americanus*, and northern corn root worm *Diabrotica barberi*. However, her study was not conclusive as to the exact pollination role of insects. Schlimgen also speculated that an alfalfa plant bug in the Miridae family *Adelphocoris lineolatus*, which she observed on an open flower of *L. leptostachya* may have been responsible for the high number of empty bracts she observed on chasmogams relative to cleistogams. This insect is reported to cause abortion and leaf abnormalities on alfalfa. Schlimgen makes no mention of the influence this insect may or may not have on seed production or other aspects of *L. leptostachya*.

L. leptostachya seeds are thought to be dispersed by gravity and through animal activities, particularly those of small mammals such as prairie voles as they feed and cache seeds. Schlimgen (1995) sites Kaufman who indicated that voles may carry seeds up to 25 meters. Clewell (1966b) also indicated that the principal means of dispersal of *Lespedezas* might be by animals that eat the seeds but do not digest all of them, thereby passing viable seed in their feces. He provides the example of bobwhite quail passing undigested *Lespedeza* seeds, which then demonstrated 100 percent germination. He also mentions Burtons and Andrews' 1948 study in which they obtained up to 12 percent recovery of viable seeds of the Asian annual *L. striata* from the feces of cattle.

In addition, Clewell (1966b) noted a 60 percent germination rate (after scarification) of *Lespedeza* seed removed from a 55 year old herbarium specimen. Alverson (1981) hypothesized that this characteristic enabled the reoccurrence of *L. leptostachya* at Shluckebier Prairie in Sauk County, Wisconsin, which had been plowed some 50 years earlier. However, Smith et al. (2002) concluded that the long-term seed bank for this species is negligible at Prairie Bushclover Scientific and Natural Area in Jackson County, Minnesota.

Prairie bushclover generally occupies north-facing slopes of 10 - 15 degrees, although some populations occur on lesser-angled slopes (Moats 1992). The soils are typically composed of fine silty loam, fine sandy loam or clay loam (U.S. Fish and Wildlife Service 1988). A pilot study on soils at three selected *L. leptostachya* sites in Iowa by Smith (1990) concluded only a tenuous relationship existed between soil types and distribution of individuals within *L. leptostachya* populations at Anderson Prairie, Emmet County, Iowa; and Cayler Prairie, Dickinson County, Iowa; although there appeared to be a strong relationship at Madison Prairie, Clarke County, Iowa.

Schlimgen (1995) cites Larson's work in 1983 during a preliminary study of soils at Westport Drumlin near Madison, Wisconsin that suggested shallow soils at that prairie may have been hindering *L. leptostachya* establishment on part of the drumlin. Schlimgen (1995) further notes that in 1992 Anderson studied soils at Bush Clover Prairie in Grant County, Wisconsin and determined that the *L. leptostachya* population occurred on silt loam soil, compared to nearby sandy loam that did not support *L. leptostachya*. She goes on to mention that Anderson also found that the soils at Bush Clover Prairie were extremely low in phosphorous, at 1-3 parts per million.

The Federal Recovery Team (U. S. Fish and Wildlife Service 1988) speculated that *L. leptostachya* individuals live 10 years or more. During an 11 year study of *L. leptostachya* plants at Prairie Bushclover Scientific and Natural Area in Jackson County, Minnesota, Smith et al. (2002) found a high rate of attrition for seedlings, with less than 50 percent surviving from their first to second year. They also found that subsequent mortality continues through the first decade of life, but is lower than that of seedlings in their first year. They found that the earliest flowering to take place in monitored individuals was by a three year old plant, with a quarter of all plants flowering by 6 to 7 years of age and over half flowering by 8 to 9 years of age. Schlimgen (1995) observed limited seed production in some 2 year old plants, with more substantial seed production in the third or fourth years at Westport Drumlin in Dane County, Wisconsin.

Smith et al. (2002) speculated that the slow advancement of plants from seedling to flowering may be typical of a long-lived perennial herb. They found that transition between size classes for non-flowering individuals was common, but that it was relatively common for flowering plants to remain in the same stage from year to year. Schlimgen (1995) also observed that monitored *L. leptostachya* plants have a tendency to stay in the same size class from year to year at Westport Drumlin in Wisconsin.

Schwegman (1990) reported *L. leptostachya* to have the ability to remain latent (not produce above-ground plant material) for several years as a response to environmental stress. In separate studies, Smith et al. (2002), and Schlimgen (1995) also found that dormancies of up to two years were common, and that individuals have the ability to endure several episodes of dormancy during a lifetime.

In several monitored populations, including those at Nachusa Grasslands, Westport Drumlin, and Madison Prairie, *L. leptostachya* has also demonstrated the capacity for rapid and dramatic population increases (Bittner and Kleiman 1999, Schlimgen 1995, Zager 1993).

Response of Prairie Bushclover to Burning and Grazing

Selby (1988) reported *L. leptostachya* individuals at Freda Haffner Kettlehole Preserve in Dickinson County, Iowa exhibited an increase in stem numbers the year of a fire and then returned the next year to their preburn level. Selby (1988) also noted a reduction of stem height the year of a spring fire and an increase the following year. The plants returned to the taller preburn height the second year after the burn. Zager (1993) observed similar responses to fire for *L. leptostachya* at Madison Prairie, Clarke County, Iowa. He concluded that the burn stimulated recruitment of *L. leptostachya* seedlings, maintained plant vigor, and increased the number of stems per plant, although each stem had reduced flower and seed production the year of a burn. Conversely, Smith, et al. (2002) and Bittner and Kleiman (1999) concluded that fire had no effect (positive or negative) on *L. leptostachya* during their respective studies.

Zager (1993) reported light grazing increased seedling recruitment and the number of ramets per individual. He concluded that reaction of individuals subjected to moderate grazing was intermediate between those which received burn treatment and those which received no burning or just light grazing. At Nachusa Grasslands in Illinois, Bittner and Kleiman (1999) suspected that light to moderate periodic grazing played an important role in maintaining populations of *L. leptostachya* by reducing interspecific competition and increasing soil disturbance that subsequently increases seedling establishment. Further, they suspected that a lack of periodic disturbance that was light to moderate in intensity was mainly responsible for a reduction in plant numbers after 1991 at Nachusa Grasslands. Bittner (pers. comm.) has also observed that *L. leptostachya* is avoided by cattle under light to moderate grazing, but is consumed under more intense grazing pressure.

Zager (1993) observed *L. leptostachya* individuals in dense forb vegetation (approximately 1,400 stems per square meter) to be less robust and less fertile; and some to be latent or not survive. Seedling recruitment was reduced or nonexistent under these dense habitat conditions. He also noted there was little recruitment of individuals where there was no grazing and no burning. Bittner and Kleiman (1999) concluded that as the quality of the prairie, and interspecific plant competition increased, and the frequency of soil disturbance decreased, the *L. leptostachya* population at Nachusa Grasslands declined.

The Prairie Bush Clover Recovery Team of Smith, Harrison, Martin, Roosa, Sather and Schwegman (1988) proposed that the following tasks be undertaken with regard to *Lespedeza leptostachya* to meet the recovery objective and to be considered for delisting 1) protect selected viable populations and their habitat, 2) provide appropriate management at each protected site, 3) inventory to locate additional populations, 4) monitor populations trends at known sites, 5) establish artificial seed banks for selected populations, 6) provide appropriate public information, 7) conduct appropriate research including habitat parameters, species and population biology and the response of populations to a variety of potential management techniques.

Madison Prairie in Clarke County, Iowa is the most southern known location of the peripheral populations. It has been used as pasture for cattle, but has not been plowed. The population of prairie bushclover was first identified on the site in 1981 by

Dorothy Barringer. Two exclosures were constructed on the site within the *L. leptostachya* population in 1986 by employees of the Clarke County Conservation Board to provide for the comparison of the effects of grazing on *L. leptostachya*. In the summer of 1986, Dean Roosa and Bill Pusateri reported approximately 200 individuals. During an initial census in 1989, Scott Zager and Carole Kern noted over 3,000 *L. leptostachya* ramets on the site (Zager, Smith, and Kern 1990). Zager and Kern established permanent plots in 1989 at Madison Prairie in Clarke County, Iowa to provide for long-term monitoring of *L. leptostachya* (Zager Smith, and Kern 1990). In 1993, Zager reported on observations at the site and noted trends in the population.

Purpose of the Study

Since *L. leptostachya* was listed by the U. S. Fish & Wildlife Service, much has been learned about this species, and more populations have been located. However, in 1993 when this study was initiated, additional information was needed to more fully understand population trends, the effects of fire and grazing, response to competition, length and periodicity of dormancy, and individual plant longevity. It was decided to reactivate and extend the three year study of Zager (1993).

It was determined that the data collected as part of this study would be combined with the Zager study for analysis to provide more data for long-term comparisons. Therefore, more inclusive long-term data could be gained regarding dormancy and longevity of individual *L. leptostachya* plants, longer term changes in *L. leptostachya* and other species could be measured, and the effects of grazing and fire on the populations could be more fully assessed.

Statement of the Problem

This long-term study was used to assess the following hypotheses:

1) The life span of *Lespedeza leptostachya* is short for a perennial.

2) Dormancy is common in *Lespedeza leptostachya*.

3) Fire stimulates growth of *Lespedeza leptostachya* plants and an increase in population numbers.

4) Grazing causes an increase in *Lepedeza leptostachya* populations.

5) Dense cover of competitive associate plant species causes a decline in *Lespedeza leptostachya*.

CHAPTER 2

METHODS

The Study Area

Madison Prairie is located in NW ¼, NE ¼, Sec. 35, T73N, R27W, Clarke County, Iowa, approximately two miles north and one mile east of the town of Murray. In the past, this prairie has been referred to as Madison Prairie, as well as Flaherty Prairie for the family that owns the tract. It has not been plowed or tiled since European settlement, but has been used as pasture, most recently for beef cattle. The population of prairie bushclover was first identified on the site in 1981 by Dorothy Barringer. Cattle exclosures on the site within the *L. leptostachya* population were constructed in 1986 by employees of the Clarke County Conservation Board to compare the effects of grazing on *L. leptostachya*. In the summer of 1986, Dean Roosa and Bill Pusateri flagged *L. leptostachya* on the site and reported approximately 200 individuals (Zager 1990). During a census in 1989, Scott Zager and Carole Kern noted over 3,000 *L. leptostachya* ramets on the site (Zager 1990).

The soils of Madison Prairie are part of the Shelby-Lamoni-Sharpsburg association. The soil type that occurs in the study plots is Shelby loam (Chowdhery 1989). It is characterized as a moderately well-drained, moderately to slowly permeable soil of convex valley side slopes on uplands, which formed in glacial till. Soil cores of the study site indicated the ungrazed plot that was burned in 1993 (NG-BRN93) and the grazed plot (GRZD) have carbonates present between 101 and 114 centimeters, while the ungrazed, burned 1990 plot (NG-BRN90) cores showed a profile of sand, loess and till as well as some carbonates (Smith 1990).

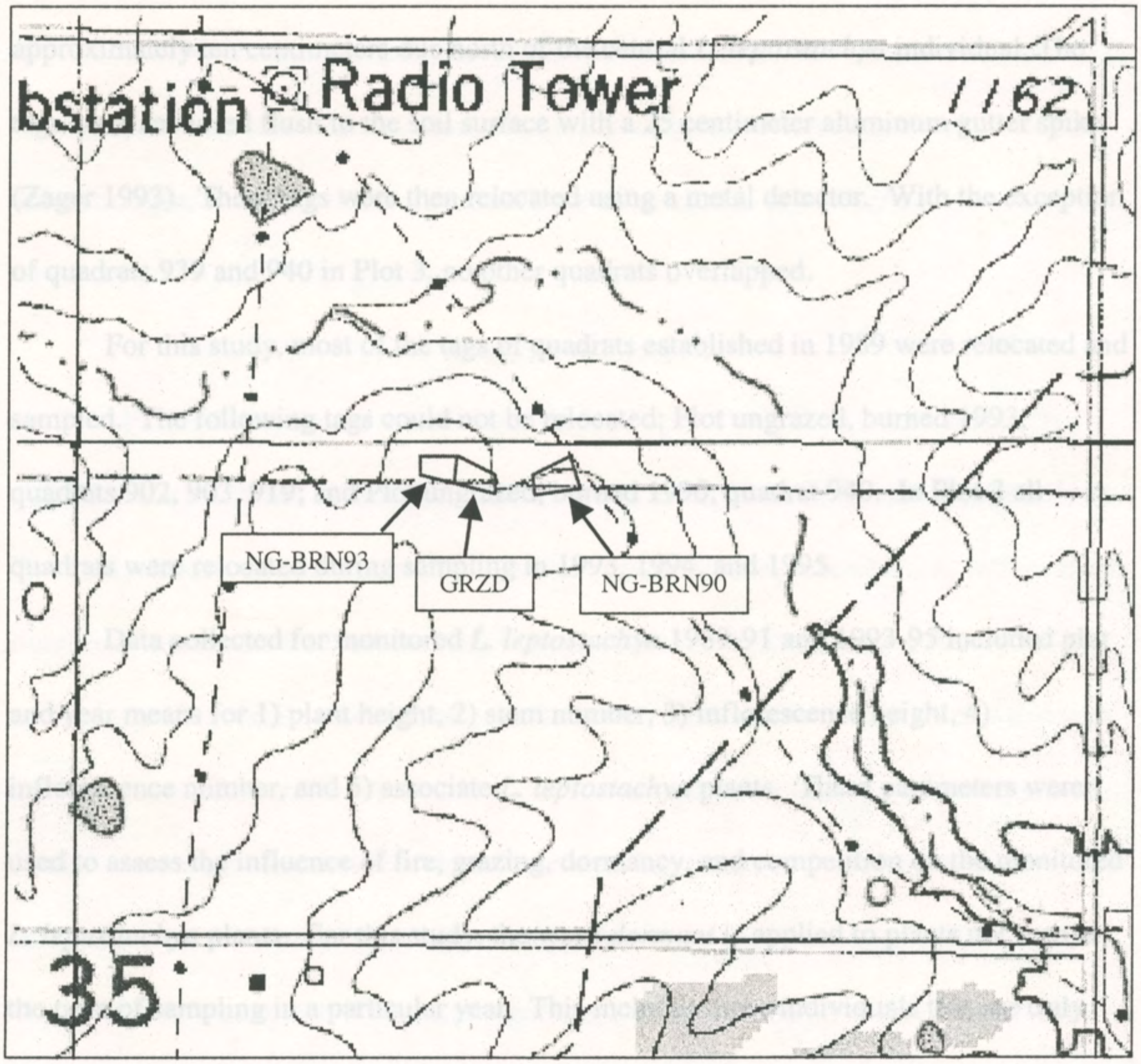
The study plots are on a north-facing slope of approximately 18-25%. The slope, aspect, and plant community composition of the ungrazed, burned 1993, and grazed plots are similar, while the ungrazed, burned 1990 plot that lies approximately 20-30 meters from the other two plots is on a slightly less steep portion of the slope and a has a more northeasterly aspect. In addition, the plot ungrazed and burned in 1990 has fewer plant species in common with the ungrazed, burned 1993 plot and the grazed plot than they have with each other.

The climate of Clarke County, Iowa is subhumid and continental. According to 1995 statistics from the National Weather Service station at Osceola, Iowa, the average annual precipitation is 89.4 centimeters. Approximately 70% of this, or 62.5 centimeters, falls between April and September. The mean July temperature is 24.1 degrees Celsius, the mean January temperature is –6.4 degrees Celsius. The number of days, in 9 out of 10 years, with a daily minimum temperature exceeding 0 degrees Celsius is 151. The average relative humidity in midafternoon is about 60%, with an average at dawn of 80%. The sun shines 70% of daytime hours during the summer. The prevailing wind is from the northwest. The highest average wind speed is 21 kilometers per hour, in the spring (Chowdhery 1989).

Experimental Design and Sampling Methods

In 1989, three permanent plots were established at Madison Prairie in Clarke County, Iowa, for long-term study of prairie bushclover *Lespedeza leptostachya* by Zager and Smith. The two ungrazed plots (NG-BRN90, NG-BRN93) had been fenced in 1986 at the recommendation of Dean Roosa, State Ecologist to exclude cattle and allow for the potential for long-term study of the population. A grazed plot (GRZD) was established adjacent to, and mirrors the ungrazed, burned 1993 plot (NG-BRN93) as shown in Figure 2 on the following page. The ungrazed, burned 1993 plot and the grazed plot measure approximately 13 meters by 30 meters, and the ungrazed, burned 1990 plot (NG-BRN90) is approximately 20 meters by 25 meters.

With this arrangement, these three plots could then be monitored under different management practices in a pseudoreplicated treatment design. One plot was not grazed during the study and burned on May 10, 1993 during a wet spring, approximately one week after emergence of most prairie plants. A second plot was grazed throughout the study period and not burned. Grazing pressure in this plot slightly increased during the study period. A third plot was not grazed during the study and burned in April 1990 while most native plants were dormant. Grazing pressure was estimated based on several parameters, including the number of cattle present in the pasture during the growing season and the height/patchiness of residual vegetation. A patchy appearance was equated with better pasture condition, whereas a more uniform appearance was associated with fair condition.



Map source: United States Geological Survey, 7.5' Quadrangle

Figure 2. Approximate Plot Layout

In 1989, an inventory of the three plots recorded a total of 550 *L. leptostachya* plants. Of these, 50 were chosen using a random function on a calculator to serve as the centers of one meter quadrats for long-term monitoring. This included 20 plants in the ungrazed, burned 1993 plot and 15 each in the plot that was grazed and the one ungrazed and burned April 1990. The quadrats were marked by an aluminum tag placed approximately ten centimeters due north of the central *L. leptostachya* individual. The tags were anchored flush to the soil surface with a 25 centimeter aluminum gutter spike (Zager 1993). These tags were then relocated using a metal detector. With the exception of quadrats 939 and 940 in Plot 3, no other quadrats overlapped.

For this study, most of the tags of quadrats established in 1989 were relocated and sampled. The following tags could not be relocated: Plot ungrazed, burned 1993, quadrats 902, 903, 919; and Plot ungrazed, burned 1990, quadrat 940. In Plot 2 all quadrats were relocated during sampling in 1993, 1994, and 1995.

Data collected for monitored *L. leptostachya* 1989-91 and 1993-95 included plot and year means for 1) plant height, 2) stem number, 3) inflorescence height, 4) inflorescence number, and 5) associate *L. leptostachya* plants. These parameters were used to assess the influence of fire, grazing, dormancy, and competition on the monitored *L. leptostachya* plants. For this study, the word *dormant* is applied to plants not seen at the time of sampling in a particular year. This includes those individuals that are truly dormant as well as those that may have recently died, or for some other reason were not present above ground at the time of sampling.

Each of the *L. leptostachya* individuals served as the center of a permanent quadrat for stratified vegetation analysis. A one-meter-square frame constructed of PVC, was centered on the selected *L. leptostachya* individual using 50 cm hash marks with a side oriented toward magnetic north. The quadrats were used to sample and to characterize the vegetation surrounding the *L. leptostachya* individuals. Within each quadrat, estimated grass cover and by-species forb stem counts were completed 1989-91, 1993, and 1994. However, this information was not collected in 1995, the last year of demographic data collection for monitored *L. leptostachya*. This data was collected to assess competition of associate plants with the monitored *L. leptostachya*.

Analysis of Results

Plot and year means were calculated for 1) plant height, 2) stem number, 3) inflorescence height, 4) inflorescence number, and 5) associate *L. leptostachya* plants. Comparisons among plots for each of the five years for these parameters, as well as mean number of associates were made using Tukey's Studentized Range test at the $p = 0.05$ level of significance for all characteristics sampled. Percent occurrence by plot and year for 1) stem number, and 2) life stage code of monitored individuals was also calculated. These values were used to assess the influence of fire, grazing, dormancy, and competition on the monitored *L. leptostachya* plants.

The mean number of forb stems per quadrat for each plot was arrived at using by-species stem count data. These means served to characterize competition that monitored *L. leptostachya* experienced, along with forb and grass Importance Values.

In addition, Importance Values were calculated for individual forb and grass species. Importance Value (IV), as defined by Cox (1996) is a synthetic statistic describing the prominence of a species in a community, calculated as the sum of its relative density, relative dominance, and relative frequency (or any two of these measurements).

Calculation of Importance Values for individual species of grasses in this study was based on estimates of percent cover, while IVs for individual forb species was based on stem counts. The IV formulas applied to grasses and forbs are given immediately below.

Grass IV = Relative Cover + Relative Frequency

Forb IV = Relative Density + Relative Frequency

In calculating Importance Values for grasses, Relative Cover equals the sum of Percent Covers of an individual species for all quadrats within a Plot, divided by the sum of Percent Covers for all grass species in all quadrats within a plot.

In calculating Importance Values for forbs, Relative Density equals the sum of stem counts of an individual species for all quadrats within a Plot divided by the sum of Percent Covers for all grass species in all quadrats within a plot.

For the calculation of both grass and forb Importance Values, Relative Frequency equals the number of quadrats that a particular species occurs in within a particular plot divided by the sum of the number of times all species occur in quadrats for a particular plot.

Since Importance Values are a summation of two relative values, they can not be directly compared across communities, or from year to year. However, the frequency and magnitude of changes in rank do provide an indication of the stability of a community. To compare the stability of the plots over time, changes in rank from year to year were summed for the grasses and top 10 ranking forbs. As no samples were taken in 1992, only the changes from 1989-1990, 1990-1991 and 1993-1994 were summed. This provided a composite score for comparing the stability of the study plots.

Information from Schram (1976, 1992), Betz (1984), and Weaver (1968) was used to characterize individual species of forbs as competitive based on their observations in prairie remnants, pastures, and restorations/reconstructions. Species identified as competitive by Schram (1976, 1992) and Betz (1984) were those which had the ability to compete against weedy species during the early years of a prairie planting, were the last to disappear from disturbed remnant praire, and/or were aggressive clone-forming species. Weaver (1968), in his 50-year study of prairies in Nebraska and Iowa chronicled species competitiveness based on his observations of a species ability to endure drought and/or grazing as well as their speed of recovery from such influences (Appendix B). In addition, a plants listed by Gleason and Cronquist (1991) as characteristic of being rhizomatous was also noted.

CHAPTER 3

RESULTS

In tables in this section, the ungrazed, burned 1993 plot is referred to as NG-BRN93, the grazed plot is referred to as GRZD, and the ungrazed, burned 1990 plot is referred to as NG-BRN90. The means estimates of vigor for monitored *L. leptostachya* that produced above ground structures in a particular year are summarized in Table 1. Although these parameters cannot be directly correlated to a plant's developmental stage, they are useful to characterize long-term trends.

One ungrazed plot was burned in April of 1990. In 1991 monitored *L. leptostachya* plants in the ungrazed, burned 1990 plot showed significant increases in inflorescence number and inflorescence height. Between 1989 and 1990, monitored *L. leptostachya* in the ungrazed, burned 1990 plot exhibited a nonsignificant reduction in plant height, inflorescence number and inflorescence height. The year of the burn, monitored plants in the ungrazed, burned 1990 plot exhibited an increased mean stem number compared to the previous and the following years, although it was not significant.

The same year of the burn in the ungrazed, burned 1993 plot, monitored *L. leptostachya* showed a reduction in the inflorescence number and height, although this value was not statistically significant. There was an apparent increase in the stem number of monitored plants present the year of the burn in the ungrazed, burned 1993 plot, but it also was not significantly different from the reduced number in 1994. Since data was not collected in 1992, there is no information available to assess changes from pre-burn conditions in this plot. In 1994, the year following the burn in the ungrazed, burned

1993 plot, monitored plants showed an apparent increase in inflorescence height but a reduction in inflorescence number, neither was significant.

Table 1. Means of characteristics of *Lespedeza leptostachya* plants present in a particular year from an original sample of 50 randomly selected plants

	YEAR					
CHARACTERISTIC	1989	1990	1991	1993	1994	1995
PLANT HEIGHT[1] (cm)						
Plot NG-BRN93	61.55	54.12	40.60	38.77[4]	45.26	47.20
Plot GRZD	60.40	* 37.21	40.83	37.20	48.35	54.67
Plot NG-BRN90	68.13	65.69[5]	68.46	62.37	50.63	75.25
STEM NUMBER PER PLANT						
Plot NG-BRN93	1.20	* 1.00	1.27	1.33[4]	1.20	1.20
Plot GRZD	1.07	1.07	1.46	1.25	1.00	1.33
Plot NG-BRN90	1.33	1.77[5]	1.31	1.33	1.38	1.00
INFLORESCENCE HEIGHT[2] (cm)						
Plot NG-BRN93	16.40	16.35	9.55	3.51[4]	6.20	5.80
Plot GRZD	10.53	11.29	10.92	13.12	14.65	10.95
Plot NG-BRN90	24.60	19.23[5]	* 33.23	17.40	* 4.96	* 22.27
INFLORESCENCE NUMBER[3]						
Plot NG-BRN93	13.70	11.44	5.00	2.00[4]	0.80	2.00
Plot GRZD	15.87 *	6.50	8.92	8.25	4.75	5.17
Plot NG-BRN90	22.27	13.92[5]	* 31.54	7.00	1.38	14.25
NUMBER OF PLANTS PRESENT [*n* =] *(TOTAL NUMBER OF TAGS)*						
Plot NG-BRN93	20*(20)*	17*(19)*	11*(17)*	9*(17)*[4]	5*(17)*	5*(17)*
Plot GRZD	15*(15)*	14*(15)*	13*(15)*	4*(15)*	4*(15)*	6*(15)*
Plot NG-BRN90	15*(15)*	13*(15)*[5]	13*(15)*	6*(14)*	8*(14)*	4*(14)*

[1] Height of tallest stem.
[2] Only plants present producing flowering structures, measured from lowest fertile branch.
[3] Number of penultimate fertile branches on the inflorescence on the tallest stem, includes all plants present.
[4] Burned May 10, 1993
[5] Burned April 1990
* Significant between-year comparisons at the p = 0.05 level using Tukey's studentized range t test (Sokal et al. 1968)

The number of stems produced per plant each year varied from 1 to 4. Percent occurrence of number of stems per plant for each plot and year is given in Table 2. The percent occurrence of different life stages of monitored plants is provided in Table 3. Plants that were not present included those that were dormant or had died. Most of the plants present in all plots throughout the study were single-stemmed, adult-sized plants. However, the ungrazed, burned 1990 plot had more plants with multiple stems than the other two.

Table 2. Percent occurrence of number of stems for 50 randomly selected *Lespedeza leptostachya* individuals

		YEAR					
PLOT	Stem #	1989	1990	1991	1993	1994	1995
NG-BRN93	0*	0%	10%	35%	47%	71%	71%
17-20 Quadrats[1]	1	80	90	53	35	23	23
	2	20	0	6	18	6	6
	3	0	0	6	0	0	0
GRZD	0*	0	7	14	73	73	73
15 Quadrats[1]	1	93	86	60	20	20	20
	2	7	7	21	7	7	7
	3	0	0	7	0	0	0
NG-BRN90	0*	0	20	14	57	43	71
14-15 Quadrats[1]	1	73	40	60	29	43	29
	2	27	26	26	14	7	7
	3	0	7	0	0	7	0
	4	0	7	0	0	0	0

* Represents plants that were dormant or no longer exist

[1] Missing quadrat tags include: (1991) Plot NG-BRN93 - 2 tags; (1992) Plot NG-BRN93 - 3 tags; (1993-1994) Plot NG-BRN93 - 3 tags and plot NG-BRN90 - 1 tag.

Tables 2 and 3, along with the raw data (Appendix A) tracking the fate of monitored individual *L. leptostachya* illustrate that dormancy, including plants that had died, was generally more frequent during the course of the study in the ungrazed, burned 1993 plot than in grazed plot, and least frequent in the ungrazed, burned 1990 plot. Monitored individuals in all plots showed an increase in absence/dormancy throughout the study period.

Table 3. Percent occurrence of life stages of monitored *Lespedeza leptostachya* plants (1989-91 and 1993-95)

PLOT	Lifestage*	YEAR 1989	1990	1991	1993	1994	1995
NG-BRN93	0	0%	28%	28%	47%	70%	70%
17-20 Quadrats[1]	1	0	17	34	0	12	0
	2	45	0	22	18	12	18
	3	55	18	17	29	0	6
	4	0	39	0	6	6	6
GRZD	0	0	27	20	73	73	60
15 Quadrats[1]	1	0	33	27	7	0	0
	2	47	0	33	7	7	7
	3	53	7	20	7	0	13
	4	0	33	0	6	20	20
NG-BRN93	0	7	13	13	57	43	71
14-15 Quadrats[1]	1	0	0	13	0	14	0
	2	53	34	14	0	7	0
	3	33	0	60	14	21	7
	4	7	53	0	29	14	21

* Lifestage codes: (0) no plant present, (1) immature, small, or otherwise poorly developed plant less than 11cm in height with no reproductive structures, (2) adult-sized plant >11cm with no reproductive structures, (3) plants producing flowers, (4) plants with fruits.

[1] Missing quadrat tags include: (1991) Plot NG-BRN93 - 2 tags; (1992) Plot NG-BRN93 - 3 tags; (1993-1994) Plot NG-BRN93 - 3 tags and plot NG-BRN90 - 1 tag.

The life stages for monitored *L. leptostachya* in the year prior to one and two year dormancies are listed in Tables 4 and 5, respectively. During the course of the study, it was observed that plants which produced reproductive structures in a particular year were less likely to be dormant the following year than those that did not flower. Prior to one year dormancies, 20 non-reproductive plants went dormant compared to 10 that flowered or fruited. In the case of two (or more) year dormancies, there were 7 nonreproductive plants that went dormant compared to 2 that flowered or fruited.

Table 4. Lifestages of monitored *Lespedeza leptostachya* plants the year prior to a year of dormancy/absence*

LIFE STAGE	PLOT NG-BRN93	PLOT GRZD	PLOT NG-BRN90	TOTAL
Seedling (< 11 cm)	2	2	4	8
Non-reproductive (>11 cm)	7	4	1	12
Flowering	3	1	2	6
Fruiting	2	2	0	4

* for the paired years: 1989-1990, 1990-1991, 1993-1994, 1994-1995.

Table 5. Lifestages of monitored *Lespedeza leptostachya* prior to 2 or more years of dormancy/absence*

LIFE STAGE	PLOT NG-BRN93	PLOT GRZD	PLOT NG-BRN90	TOTAL
Seedling (< 11 cm)	1	0	1	2
Non-reproductive (>11 cm)	3	2	0	5
Flowering	2	0	0	2
Fruiting	0	0	0	0

*For the periods 1989-1991 and 1993-1995

Demographic data (Appendix A) showed that during the paired years of 1990-1991, 1993-1994, and 1994-1995, there was an overall 14.7%(17/116) occurrence of being dormant in the first year monitored and present the second year. For the same paired years there was a 67.2% (78/116) occurrence of being in the same condition (either present or absent) for two consecutive years. There was also an 18.1% (21/116) occurrence of being present the first year and dormant/absent the second. Dormancy increased among all plots during the study period. In the1995 growing season, dormancy of monitored individuals for all plots exceeded 67% (31 of 46 individuals). Plants absent for more than two years in 1995 and presumed dead exceeded 45% (21 of 46 individuals). Returning from one year of dormancy was common among monitored individuals in all three plots, it occurred 11 times. However, returning from two successive years of dormancy was very unusual during this study, with only two plants doing so.

Returning from a second period of dormancy was also uncommon during the study period, as only one individual returned from two separate one year periods of dormancy. No monitored individuals reappeared after being listed as dormant for more than two successive years.

Dormancy occurred least often in the ungrazed, burned April 1990 plot. Monitored plants in the grazed plot exhibited slightly less dormancy than in the ungrazed, burned May 1993 plot and slightly more than those in the ungrazed, burned April 1990 plot (Appendix A). During the 1995 growing season a total of 21 of the 46 monitored individuals (four tags were not relocated from the original 50 tagged) from all three plots had been missing for a total of three consecutive years.

During the course of the study, plant height showed greater variability, as well as an overall decline in the ungrazed, burned 1993, and grazed plots, compared to the ungrazed, burned 1990 plot. The ungrazed plot that was burned in 1993 also had a greater overall decline in inflorescence height and number throughout the study compared to plants the other plots.

There was a considerable decline in the number of monitored *L. leptostachya* plants present in a given year. From 1989 to 1991 there number of plants in ungrazed, burned May 1993 plot decreased from 20 plants present out of 20 tags to 11 out of 17, while those in the grazed, and ungrazed, burned 1990 plots only declined by 2 from the original 15. When plots were resampled in 1993, *L. leptostachya* in grazed plot and the ungrazed, burned 1990 plot had declined by nine and seven respectively from 1991. At the conclusion of the study, the percentage of non-dormant *L. leptostachya* was 25% in the ungrazed, burned 1993 plot, 40% in the grazed plot, and 27% in the ungrazed, burned 1990 plot. It is important to note that because of the declining numbers of individuals present during the later years of the study it became increasingly difficult to make statistical comparisons for these characteristics.

Mean number of associate *L. leptostachya* per quadrat is listed by plot in Table 6. The mean number of associate *L. leptostachya* plants in the ungrazed, burned 1990 plot was higher that year than either the previous or following years, although the differences were not statistically significant. This rise in associates from 1989 to 1990 and the fall from 1990 to 1991, follows the trend of precipitation during the growing seasons (Figure 3). However, this correlation did not hold true for the 1993 growing season.

Table 6. Mean number of associate *Lespedeza leptostachya* plants within monitored quadrats[1]

PLOT	YEAR 1989		1990		1991		1993		1994
NG-BRN93	2.00		2.11		0.47		0.53		0.53
GRZD	1.20	*	2.80	*	1.40		2.27	*	0.67
NG-BRN90	1.73	*	4.00	*	1.33		1.43		0.86

[1] does not include monitored plant

*significant between-year comparisons at p = 0.05 level using Tukey's Studentized Range

The mean number of associates in the ungrazed, burned April 1990 plot showed a significant rise from 1989 to 1990 and a significant decline from 1990 to 1991. The number of associates in the ungrazed plot burned in 1990 (4.00/m^2) was the highest for all plots, in all years. The plot burn in 1990 took place during a year of above average rainfall compared to either the previous or following years (Figure 3). The rainfall during the growing season in 1989 was 13.7 centimeters below average, and was 9.3 centimeters below average in 1992. The mean number of associate *L. Leptostachya* between 1993 and 1994 showed no significant difference. In the ungrazed, burned 1990 plot, monitored and associate plants declined in number during the course of the study, although the apparent decrease in monitored individuals was greater.

There was no significant influence on the number of *L. leptostachya* associates from the prescribed fire in 1993. No data was collected in 1992 prior to the fire. There was no significant difference in the mean number of associates in the ungrazed, burned 1993 plot between any of the years, although there was an overall decline from a mean of between 2.00 associates per quadrat in 1989 to 0.53 in 1994. Both monitored and associate *L. leptostachya* showed a general downward trend of numbers in the ungrazed, burned 1993 plot throughout the course of the study. This coincided with a sharp rise in the mean number of forb stems per quadrat in this plot, from 74.2 in 1989 to 143.6 in 1994 (Table 7).

The mean number of associate *L. leptostachya* in the grazed plot in 1990 was significantly higher than the mean of both the previous and the following years. It was 2.8 in 1990, 1.2 in 1989, and 1.4 in 1991. The mean number of grazed plot associates for 1993 was also significantly higher than that of 1994. In this instance, the mean was in excess of three times greater.

Across all plots, the number of associate *L. leptostachya* plants declined and was considerably lower at the end of the study. This trend is similar to that of the monitored *L. leptostachya,* but not as precipitous.

Table 7 lists mean forb stem count per quadrat by-plot. The ungrazed, burned 1990 plot had a mean forb stem count of over 157 in 1990 after it was burned in April of that year. The greatest mean number of forbs per quadrat for all samples was 193 after a May burn in the ungrazed, burned 1993 plot. Both plots experienced a mean forb stems per quadrat increase of 2.2 to 2.3 times the year of a burn. The ungrazed, burned 1990 plot returned to near preburn levels the next year, whereas forb stem counts remained elevated the next year in the ungrazed, burned 1993 plot. Mean forb stem count remained relatively constant in the grazed plot throughout the study.

In the grazed plot, the lowest mean number of forb stems per quadrat (41.7) was observed in the 1991 growing season under moderate to severe grazing. However, the

Table 7. Mean forb stems per quadrat

		YEAR				
PLOT	*Quadrats**	*1989*	*1990*	*1991*	*1993*	*1994*
NG-BRN93	17-20	74.2	76.6	86.5	193.1[1]	143.6
GRZD	15	55.2	66.2	41.7	84.1	54.5
NG-BRN90	14-15	68.5	157.3[2]	68.8	68.4	71.7

* Missing quadrat tags include: (1991) Plot NG-BRN93 - 2 tags; (1992) Plot NG-BRN93 - 3 tags; (1993-1994) Plot NG-BRN93 - 3 tags and plot NG-BRN90 - 1 tag.

[1] burned May 13, 1993

[2] Plot 3 burned April, 1990

mean number of forb stems per quadrat reached a high of 84.1 in 1993, despite moderate to severe grazing that year.

Madison Prairie has been grazed at varying lengths and intensities in the past. Information regarding recent grazing patterns is listed in Table 8. Grazing has been excluded from two of the plots since 1986. During the study period, the heaviest grazing took place during the years 1991 and 1993. This coincided with years of slightly below normal and dramatically above normal precipitation years, respectively. In addition to noting the grazing pressure throughout the pasture, it was also observed that under light to moderate grazing the beef cattle on Madison Prairie did not selectively graze *L. leptostachya.*

Importance Values for grasses and forbs for all plots are provided in Tables 9-14. Importance Values for grasses in the ungrazed, burned 1993 plot are shown in Table 9. Dominant grass species in the ungrazed, burned 1993 plot which had nearly constant IVs included *Schizachyrium scoparium* and *Sporobolus heterolepis. Schizachyrium*

Table 8. Grazing history at Madison Prairie*

Year	Grazing Pressure[1]
1984	Flaherty family reported heavy grazing this year.
1986	Flaherty family graze 10-15 head of cattle, beginning in August.
1987	May - September 30, Flaherty's report grazing by 13 heifers and 1 bull.
1988	May 1 - September 30, Flaherty's report grazing by 9 heifers and 1 bull.
1989	Light to moderate grazing through summer, with late fall grazing of 60 head of cattle.
1990	Light to moderate grazing throughout the growing season.
1991	Moderate to severe grazing throughout growing season (vegetation grazed to less than 10cm in height).
1992	No information available.
1993	Moderate to severe grazing during the growing season, 30 - 40 head of cattle seen in pasture (vegetation grazed to less than 10cm in height).
1994	Light to moderate grazing during growing season by 18 head of cattle.
1995	Moderate grazing during growing season by 24 head of cattle.

* Pasture totals 120 acres. Information for 1984-1991 adapted from Zager, et al. (1990)
[1] Grazing pressure estimated based on number of cattle and height/patchiness of residual vegetation

scoparium was the dominant grass throughout the study in this plot, with the exception of 1994, the after a year burn when *Sorghastrum nutans* and *Andropogon gerardii* increased dramatically in importance and rose to first and second rank in IV, respectively. There was a dramatic decline of *Andropogon gerardii* and *Sorghastrum nutans* in 1990 and 1991, but by 1994 they recovered to levels that greatly exceeded even their 1989 values. Conversely, *Poa pratensis* showed a rise in IV from 9.0 in 1989 (5th rank) to 32.7 in 1991

Table 9. Plot with no grazing, burned May 1993 – Grass Importance Values* derived from stratified vegetation analysis of 17-20 quadrats with centric *Lespedeza leptostachya* individuals

	Year				
Species	*1989*	*1990*	*1991*	*1993*	*1994*
Schizachyrium scoparium	31.8	42.0	32.7	23.5	36.5
Andropogon gerardii	27.3	12.3	9.8	20.3	39.4
Sorghastrum nutans	24.4	6.4	16.8	16.7	56.9
Sporobolus heterolepis	20.3	35.9	18.2	14.0	21.1
Poa pratensis	9.0	15.4	32.7	10.3	7.6
Bouteloua curtipendula	6.5	6.7	4.6	2.3	0.0

* Importance Value = Relative Cover + Relative Frequency

(1st rank), but fell back to 7.6 by 1994 (5th rank). *Bouteloua curtipendula* had the lowest IV rank (6th) each year of all the sampled grasses throughout the study and was the only grass that declined steadily in IV throughout the study period in this plot.

Importance Values for forbs in the ungrazed, burned 1993 plot are summarized in Table 10. During the course of the study, IVs for most of the dominant forb species in this plot remained nearly constant or increased. *Solidago canadensis* and *Aster ericoides* were the top two ranked species in IV, respectively in this plot in 1989. In 1990 these two species traded places in IV rank, with *Aster ericoides* remaining top ranked for the remainder of the study. *Pycnanthemum virginianum*, *Aster oolentangiensis*, and *Coreopsis palmata* were third, fourth and fifth ranked, respectively in 1989. During the 1993 and 1994, *Coreopsis palmata* had improved to third rank while *Pycnanthemum virginianum* and *Aster oolentangiensis* had dropped to fourth and fifth rank, respectively. *Lespedeza leptostachya* associates dropped from sixth to eighth in IV rank from 1989 to

Table 10. Plot with no grazing, burned May 1993 – Forb Importance Values* of 17-20 quadrats with centric *Lespedeza leptostachya* plants

Species	*Year* 1989	1990	1991	1993	1994
Solidago canadensis	21.6	22.1	22.5	20.4	18.1
Aster ericoides	18.9	27.1	26.7	30.7	39.8
Pycnanthemum virginianum	15.7	15.9	18.8	16.9	14.6
Aster oolentangiensis	13.4	14.9	15.0	10.1	11.0
Coreopsis palmata	10.6	14.3	12.5	18.6	16.0
Achillea millefolium	8.3	10.0	11.0	9.3	9.9
Euthamia graminifolia	8.4	8.1	8.5	8.0	6.2
Lespedeza leptostachya (associates)	7.7	10.6	2.4	2.2	2.2
Rosa spp.	7.5	8.9	7.5	7.0	7.2
Brickellia eupatoroides	7.0	7.7	9.3	7.5	5.2
Lithospermum canescens	6.6	8.5	4.8	7.0	7.4
Carex bicknellii	6.5	0.0	3.4	0.0	1.7
Lespedeza capitata	3.4	3.2	2.8	3.9	2.9
Solidago speciosa	2.5	1.1	3.3	2.4	2.8
Amorpha canescens	2.4	4.0	1.4	1.2	0.6
Baptisia bracteata	2.4	1.7	0.6	0.4	1.0
Senecio spp.	2.3	2.2	4.7	3.0	5.1
Solanum corolinense	2.3	0.0	0.0	0.0	0.0
Anemone cylindrica	2.2	3.0	1.6	4.6	4.6
Heuchera richardsonii	2.2	3.5	2.4	2.6	3.4
Lotus corniculatus	2.2	0.8	0.0	0.0	0.0
Aster pilosus	2.1	0.6	1.1	1.6	0.4
Symphoricarpos orbiculatus	1.9	2.7	3.4	2.0	2.8
Ruellia humilis	1.9	0.6	0.0	0.0	1.9
Viola pedatifida	1.8	0.8	1.7	2.8	4.9
Fragaria virginiana	1.5	0.0	1.3	1.3	0.8
Ratibida pinnata	1.4	1.1	1.2	1.3	3.2
Antennaria neglecta	1.2	0.0	1.0	0.0	0.0
Echinacea pallida	1.0	1.2	0.0	0.9	1.0
Asclepias verticillata	1.0	3.5	0.0	0.0	0.0
Agrimonia parviflora	1.0	1.3	1.9	1.2	0.0
Heliopsis helianthoides	0.9	0.7	0.6	0.4	1.1
Physalis virginiana	0.5	0.0	0.0	5.3	2.4
Lespedeza leptostachya X capitata	0.5	0.6	0.6	0.4	0.0
Oxalis spp.	0.0	0.0	0.0	3.1	1.5

* Importance Value = Relative Frequency + Relative Density

1990 and dropped below thirteenth rank in 1991 and remained below that level through 1994.

Overall, species with IVs that remained nearly constant include *Solidago canadensis, Pycnanthemum virginianum, Aster oolentangiensis, Achillea millefolium, Euthamia graminifolia, Rosa spp., Brickellia eupatoroides* and *Solidago speciosa.* Dominant forbs with increasing IVs through the study were *Aster ericoides* and *Coreopsis palmata.* Other forbs with decreasing IVs included *Lespedeza leptostachya* (associates), *Carex bicknellii, Amorpha canescens, Aster pilosus, Baptisia bracteata, Solanum carolinense* and *Asclepias verticillata.*

Importance Values for grass cover in the grazed plot is shown in Table 11. Of the grasses in the grazed plot, only *Schizachyrium scoparium* remained relatively constant. It was top ranked in IV in 1989, and remained in second or third rank in IV through 1994 making it one of the most important grasses throughout the study in this plot. Minor fluctuations of *Schizachyrium scoparium* tended to be similar to changes in growing season precipitation (Figure 3). As well, the study period IV low for *Schizachyrium scoparium* occurred during 1993 when an extraordinarily wet year coincided with a year of intense grazing. *Sporobolus heterolepis* showed some fluctuations in IV, including dramatic declines in 1991 and 1993, which were years of heavy grazing. Both *Sporobolus heterolepis* and *Schizachyrium scoparium* declined during the wet year of 1993.

Grasses that showed an overall increase in the grazed plot were *Andropogon gerardii* and *Sorghastrum nutans,* although both of these did poorly under the heavy

Table 11. Plot grazed, no burning – Grass Importance Values* derived from stratified vegetation analysis of 15 quadrats with centric *Lespedeza leptostachya* individuals

Species	1989	1990	Year 1991	1993	1994
Schizachyrium scoparium	44.9	35.2	38.1	16.3	33.5
Sorghastrum nutans	18.7	16.1	15.0	15.4	38.2
Bouteloua curtipendula	15.8	2.5	13.8	2.8	4.2
Poa pratensis	15.7	40.4	43.1	17.0	6.8
Sporobolus heterolepis	14.3	35.7	18.2	10.8	22.3
Andropogon gerardii	7.4	12.3	6.5	18.5	26.2

* Importance Value = Relative Cover + Relative Frequency

grazing and below normal rainfall of 1991. *Sorghastrum nutans* was second rank in IV in 1989, dropped to fourth in 1990 and 1991, improved to third in 1993 and was the top ranked grass in 1994. Neither *Andropogon gerardii* nor *Sorghastrum nutans* were as important in the grazed plot as they were in the ungrazed, burned 1993 plot. However, they increased in importance under heavy grazing in a year with above average precipitation (1993), and reached study period highs during the 1994 growing season.

The IVs of *Poa pratensis* rose from 15.7 in 1989 to become the top ranked grass in 1990(40.4) and 1991(43.1), and then fell to fifth place(6.8) in 1994. The dramatic decline of *Poa pratensis* from 1991 to 1994 coincided with the increase in IV's for both *Sorghastrum nutans* (15.0 to 38.2) and *Andropogon gerardii* (6.5 to 26.2).

Table 12 summarizes the Importance Values for forbs in the grazed plot. Dominant forbs in this plot with nearly constant IVs over the course of the study period include *Pycnanthemum virginianum, Solidago canadensis, Aster oolentangiensis,*

Table 12. Plot Grazed, no burning – Forb Importance Values* of 14-15 quadrats with centric *Lespedeza leptostachya* plants

Species	Year 1989	1990	1991	1993	1994
Pycnanthemum virginianum	16.0	8.4	16.6	10.7	8.2
Solidago canadensis	15.7	14.6	16.2	15.7	13.8
Euthamia graminifolia	12.8	9.7	10.3	11.5	15.2
Rosa spp.	12.5	13.2	16.2	10.1	11.3
Aster oolentangiensis	11.8	15.9	15.1	14.9	14.2
Brickellia eupatoroides	10.8	8.3	14.1	5.0	7.1
Solidago speciosa	10.4	8.8	0.0	2.8	5.0
Achillea millefolium	9.8	11.2	12.2	6.9	8.3
Carex bicknellii	9.3	1.9	0.0	0.0	0.0
Lithospermum canescens	8.4	5.8	6.0	3.6	4.7
Viola pedata	8.2	1.5	7.2	10.3	1.3
Ambrosia psilostachya	7.7	7.9	11.6	9.6	8.5
Coreopsis palmata	7.5	5.4	4.9	3.3	3.6
Potentilla arguta	6.0	4.8	6.5	1.7	2.3
Lespedeza leptostachya (associates)	5.8	10.7	6.0	6.6	3.6
Aster ericoides	5.2	7.5	4.6	7.8	10.0
Amorpha canescens	4.6	5.4	5.4	6.5	2.0
Vernonia baldwinii	4.1	1.5	4.9	1.7	3.5
Lespedeza capitata	3.5	3.6	4.6	2.9	3.5
Aster pilosus	3.4	3.3	1.1	10.8	10.1
Anemone cylindrica	3.3	8.0	5.8	6.9	5.7
Asclepias verticillata	2.5	1.1	0.0	0.0	0.0
Gentiana puberulenta	2.2	0.0	0.0	0.0	1.1
Ruellia humilis	2.2	9.1	2.2	3.2	1.3
Baptisia bracteata	1.9	0.5	2.2	1.6	0.7
Ratibida pinnata	1.9	1.7	1.4	3.4	6.4
Comandra umbellata	1.9	0.0	0.0	0.0	0.0
Heuchera richardsonii	1.8	2.2	1.4	1.4	0.0
Baptisia lactea	1.6	1.2	0.8	1.0	1.1
Senecio spp.	1.5	9.1	5.4	6.3	7.3
Lactuca floridana	1.1	0.8	0.0	0.0	0.6
Viola pedatifida	1.1	0.0	0.8	0.6	0.7
Heliopsis helianthoides	1.0	0.7	1.9	2.5	3.2
Symphoricarpos orbiculatus	1.0	0.6	0.8	0.6	0.6
Echinacea pallida	0.6	0.8	0.8	0.4	0.0

* Importance Value = relative frequency (RF) + relative density (RD)

Lithospermum canescens, Achillea millefolium, Ambrosia psilostachya, Amorpha canescens and *Vernonia baldwinii.*

Species that exhibited a general increase in Importance Values during the study period were *Aster ericoides, Senecio spp., Anemone cylindrica, Ratibida pinnata, Heliopsis helianthoides,* and *Aster pilosus.* However, of the species with increasing IVs, only *Aster ericoides* and *Aster pilosus* were ranked among the top 20. Dominant forbs species that decreased in IV included: *Lespedeza leptostachya* (associates), *Carex bicknellii, Brickellia eupatoroides, Solidago speciosa, Coreopsis palmata, Potentilla arguta,* and *Asclepias verticillata.*

Overall, the weedy forb *Solidago canadensis* (Betz 1984, Schram 1976, 1992) was the only forb that remained near the top rank in Importance Value throughout the study in this plot. *Aster oolentangiensis* also had a relatively high importance during the study rising from eighth in IV rank in 1989 to second in 1991 and eventually declining to fifth place in 1994. With the exception of *Rosa sp.* and *Solidago canadensis*, all other forbs showed more fluctuation in Importance Value and rank throughout the study period.

Grass species Importance Values for the ungrazed, burned April 1990 plot are shown in Table 13. Grasses in this plot that had the most constant IVs include *Schizachyrium scoparium* (2nd or 3rd rank), which fared slightly poorer in cool years with high rainfall) and *Sporobolus heterolepis* (4th or 5th rank).

Andropogon gerardii IVs remained relatively constant from 1989 (26.0) to 1993 (24.4), and then rose to 50.2 in 1994. *Sorghastrum nutans* decreased in IV from 1989 to

1991 but returned to 1989 levels by 1994. *Poa pratensis* had an IV of 0.0 in 1989. It then reached a high of 22.1 in 1991, before falling back to 9.7 in 1994. The fall in IV of *Poa pratensis* coincided with a rise by *Andropogon gerardii (3rd to 1st IV rank).*

Table 13. Plot with no grazing, burned 1990 (NG-BRN90). Importance Values* derived from stratified vegetation analysis of 14-15 quadrats with centric *Lespedeza leptostachya* individuals

	Year				
Species	*1989*	*1990*	*1991*	*1993*	*1994*
Sorghastrum nutans	39.3	28.1	18.1	20.9	37.2
Schizachyrium scoparium	27.4	27.9	26.1	17.0	27.0
Andropogon gerardii	26.0	22.8	28.3	24.4	50.2
Bouteloua curtipendula	21.3	6.8	8.8	8.5	5.3
Sporobolus heterolepis	2.4	10.9	3.0	5.4	9.7
Poa pratensis	0.0	12.1	22.1	4.2	9.7

* Importance Value = Relative Cover + Relative Frequency

Bouteloua curtipendula was the only grass to steadily decrease in IV during the study period, falling from 21.3 in 1989 to 5.3 in 1994. During that period it dropped from fourth in IV rank in 1989 to sixth in 1990, rose one place in each of the next two sample years, and then dropped from 4th to 6th in 1994. *Sorghastrum nutans* was top-ranked the first two years, declined to fourth the year after the fire, and then rose to second rank by 1994. *Andropogon gerardii* ranked third the first to years, advanced to first rank the year after the fire and maintained that position through the end of the study. *Schizachyrium scoparium* ranked second the first three years of the study and then declined to third rank as *Sorghastrum nutans* and *Andropogon gerardii* gained prominence. *Poa pratensis* was relatively unimportant in this plot except for rising to third rank the year after the fire and then declining in 1993 and 1994.

The forb Importance Values for the ungrazed, burned 1990 plot are summarized in Table 14. Forbs that increased in IV during the study period include *Aster ericoides, Aster oolentangiensis, Pycnanthemum virginianum, Achillea millefolium, Lithospermum canescens, Heliopsis helianthoides, Anemone cylindrica*, and *Ratibida pinnata*. Of these, only *Aster ericoides, Aster oolentangiensis,* and *Pycnanthemum virginianum* occur in the top twenty of IV rank. Dominant species which showed relatively little change in IVs include *Solidago canadensis*, *Rosa* spp., *Viola pedata,* and *Euthamia graminifolia*.

Dominant species that decreased in IV are *Lespedeza leptostachya*, *Ambrosia psilostachya*, *Carex bicknellii*, *Coreopsis palmata,* and *Asclepias verticillata*. Many forb species in the ungrazed, burned 1990 plot demonstrated wide annual fluctuation in IV's.

Ambrosia psilostachya, Solidago canadensis and *Coreopsis palmata* were the three top-ranked species in 1989. The weedy forb (Appendix B) *Ambrosia psilostachya* ranked first through in 1989 and 1990, and dropped in rank the year after the fire when *Aster ericoides,* a competitive species (Appendix B) attained the top rank and maintained that place after 1991. The weedy forb *Solidago canadensis* (Appendix B) remained fairly constant in importance throughout the study. *Coreopsis palmata* fell dramatically in rank the year following the fire. *Aster oolentangiensis* rose to second rank in 1991 from seventh, but had fallen to fourth place by 1993.

Table 14. Plot - No grazing, burned 1990 – Forb Importance Values* of 14-15 quadrats with centric *Lespedeza leptostachya* plants

Species	1989	1990	1991	1993	1994
	Year				
Ambrosia psilostachya	32.8	28.3	19.2	13.8	15.2
Solidago canadensis	18.9	14.5	20.8	20.7	14.4
Coreopsis palmata	17.5	15.2	2.3	5.7	5.3
Rosa spp.	11.6	8.5	12.8	12.3	11.6
Aster ericoides	10.1	12.6	32.6	28.7	29.9
Lespedeza leptostachya (associates)	8.9	8.8	2.9	8.2	4.4
Brickellia eupatoroides	7.1	5.9	9.3	8.0	9.8
Aster oolentangiensis	6.5	6.2	22.5	12.5	10.7
Viola pedata	6.2	5.9	8.9	5.8	4.4
Dalea candida	5.9	2.5	4.8	6.7	4.2
Euthamia graminifolia	5.7	3.7	2.8	6.1	6.8
Asclepias verticillata	5.7	2.0	0.0	0.0	0.0
Carex bicknellii	5.4	1.4	0.0	0.0	0.0
Malus ioensis	5.3	3.6	5.5	2.6	3.6
Ruellia humilis	5.1	3.8	5.0	3.6	4.5
Lespedeza capitata	4.6	3.3	6.8	6.7	5.4
Vernonia baldwinii	3.8	1.6	2.1	0.0	1.2
Teucrium canadense	3.6	1.8	2.4	3.9	4.8
Pycnanthemum virginianum	3.1	5.5	7.4	5.4	6.7
Viola pedatifida	3.0	0.5	0.8	0.8	3.2
Potentilla arguta	2.9	1.7	2.3	0.8	1.3
Lithospermum canescens	2.8	5.6	5.5	5.1	5.3
Heliopsis helianthoides	2.7	1.4	1.2	4.6	7.1
Physalis heterophylla	2.5	1.0	0.0	4.7	0.0
Achillea millefolium	2.2	1.9	4.1	4.5	7.8
Amorpha canescens	2.2	0.5	0.0	0.0	0.8
Lysimachia ciliata	2.2	0.0	4.4	0.0	0.0
Aster pilosus	2.1	1.8	0.0	4.8	1.4
Gentiana puberulenta	1.4	0.0	0.0	0.0	1.9
Symphoricarpos orbiculatus	1.3	1.0	1.8	3.2	2.9
Anemone cylindrica	1.3	3.7	2.1	4.0	4.8
Solidago speciosa	0.8	0.8	0.7	0.0	2.0
Monarda fistulosa	0.8	0.0	0.7	0.8	1.4
Ratibida pinnata	0.7	0.6	1.0	1.8	1.9
Lactuca floridana	0.7	1.5	0.0	3.3	1.4

* Importance Value = relative frequency (RF) + relative density (RD)

Table 15 shows rank according to Importance Value for the top 13 forbs for all three plots. It provides an overview of the most dominant plants within and among the plots. Year to year changes in IV rank for forbs and grasses proved useful for comparing relative stability within and among plots.

Overall, the ungrazed, burned May 1993 plot demonstrated the least change in rankings among species. The grazed plot, and the ungrazed, burned April 1990 plots showed more dramatic rankings changes by individual forb species. This is particularly true of the grazed plot, which had the greatest year to year reordering of dominant species according to their Importance Values.

For the paired years 1989-1990, 1990-1991, and 1993-1994, the ungrazed, burned 1993 plot had a total of 30 IV rank changes, the grazed plot had a total of 48 rank changes, and the ungrazed, burned 1990 plot had a total of 44 rank changes.

Departures of temperature and precipitation from the long-term average for the growing season (April - September) for the period 1986-1995, at Osceola, Iowa is shown in Figure 3. Abnormal climatic growing seasons during the study period include the drought period of 1988-1989, as well as the remarkably wet and below average temperature year in 1993.

Table 15. – Summary of highest forb Importance Value Rankings of 13-20 quadrats with centric *Lespedeza leptostachya* plants

Species	**Plot No Grazing, Burned May 10, 1993**					**Plot Grazed**					**Plot No Grazing, Burned April 1990**					**Comp-etitive*/ clonal species**
	1989	1990	1991	1993	1994	1989	1990	1991	1993	1994	1989	1990	1991	1993	1994	
Solidago canadensis	1	2	2	2	2	2	2	2	1	3	2	3	3	2	3	x
Aster ericoides	2	1	1	1	1	-	-	-	9	6	5	4	1	1	1	x
Pycnanthemum virginianum	3	3	3	4	4	1	10	1	5	9	-	11	8	13	10	x
Aster oolentangiensis	4	4	4	5	5	5	1	4	2	2	8	7	2	4	5	x
Coreopsis palmata	5	5	5	3	3	13	-	-	-	-	3	2	-	12	12	x
Achillea millefolium	6	7	6	6	6	8	4	6	10	8	-	-	-	-	7	x
Euthamia graminifolia	7	10	8	7	9	3	6	8	3	1	11	12	-	10	9	x
Lespedeza leptostachya (associate)	8	6	-	-	-	-	5	12	12	-	6	5	-	6	-	
Rosa spp.	9	8	9	9	8	4	3	3	7	4	4	6	5	5	4	
Brickellia eupatoroides	10	11	7	8	10	6	11	5	-	11	7	8	6	7	6	x
Lithospermum canescens	11	9	10	10	7	10	-	11	-	-	-	10	11	-	13	
Carex bicknellii	12	-	12	-	-	9	-	-	-	-	13	-	-	-	-	
Lespedeza capitata	13	-	-	13	-	-	-	-	-	-	-	-	9	9	11	x
Solidago speciosa	-	-	-	-	-	7	9	-	-	-	-	-	-	-	-	x
Amorpha canescens	-	12	-	-	-	-	-	-	13	-	-	-	-	-	-	
Senecio spp.	-	-	11	-	11	-	8	-	-	10	np	np	np	np	np	
Anemone cylindrica	-	-	-	-	12	-	12	13	11	13	-	-	-	-	-	
Heuchera richardsonii	-	13	-	12	13	-	-	-	-	-	np	np	np	np	np	
Symphoricarpos orbiculatus	-	-	13	-	-	-	-	-	-	-	-	-	-	-	-	
Viola pedatifida	-	-	-	-	-	11	-	9	6	-	9	9	7	11	-	
Ambrosia psilostachya	np	np	np	np	np	12	13	7	8	7	1	1	4	3	2	x
Dalea candida	np	np	np	np	np	-	-	-	-	-	10	-	12	8	-	
Asclepias verticillata	-	-	-	-	-	-	-	-	-	-	12	-	-	-	-	x
Ruellia humilis	-	-	-	-	-	-	7	-	-	-	np	np	np	np	np	
Potentilla arguta	np	np	np	np	np	-	-	10	-	-	-	-	-	-	-	
Aster pilosus	-	-	-	-	-	-	-	-	4	5	-	-	-	-	-	
Ratibida pinnata	-	-	-	-	-	-	-	-	-	12	-	-	-	-	-	x
Malus ioensis	np	np	np	np	np	np	np	np	np	np	-	-	10	-	-	
Heliopsis helianthoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	x
Physalis heterophylla	np	np	np	np	np	np	np	np	np	np	-	-	-	-	7	
Lysimachia ciliata	np	np	np	np	np	np	np	np	np	np	-	-	13	-	-	

* Species characterized as competitive is based, in part on Betz (1984), Schram (1976, 1992), and Weaver (1968). See also Appendix B.

\- Species present in Plot, but did not rank in top 13 IV's

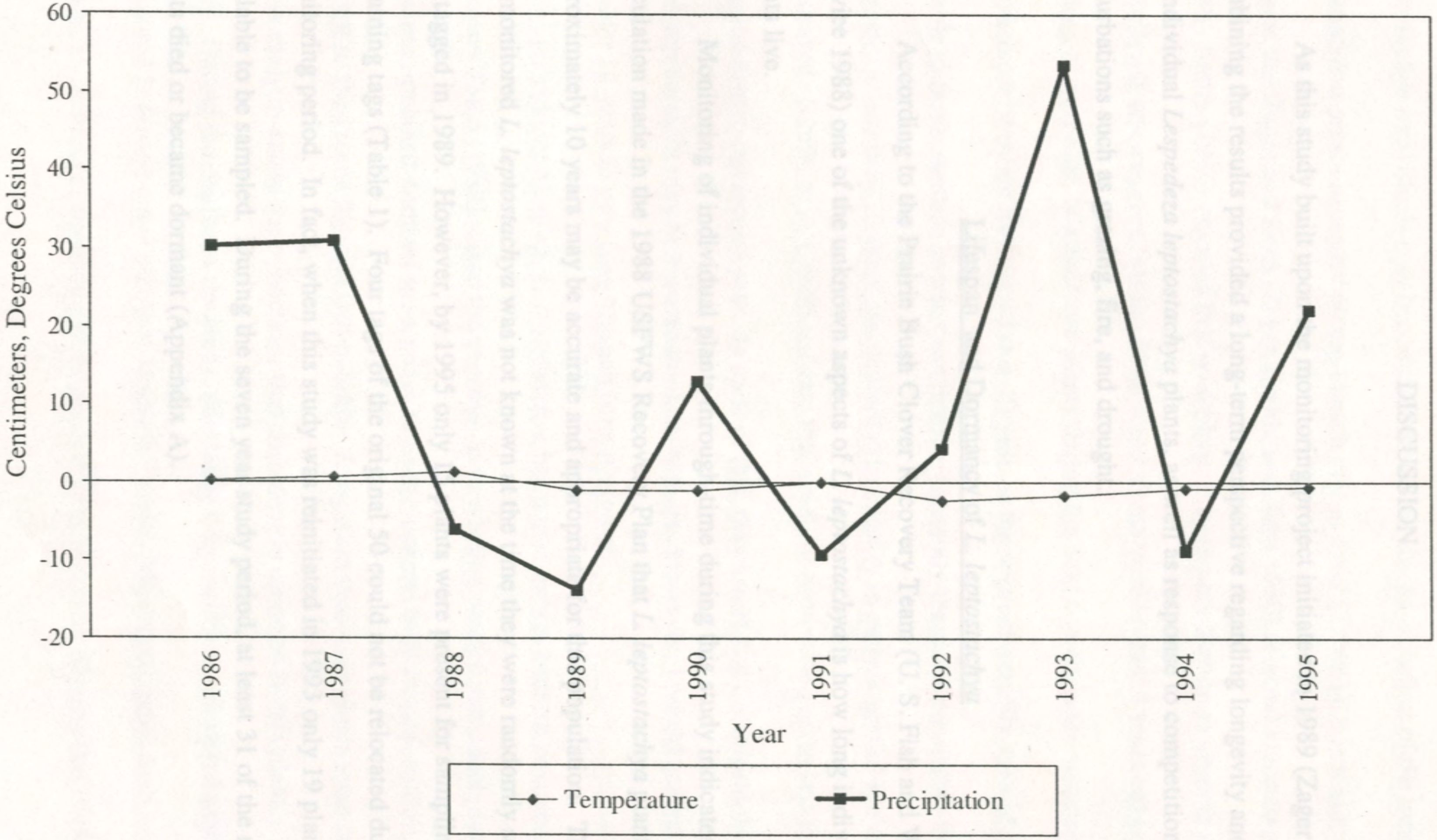


Figure 3. Departure from long-term averages for growing season temperature and precipitation at Osceola, IA (less than ten miles from Madison Prairie)

CHAPTER 4

DISCUSSION

As this study built upon the monitoring project initiated in 1989 (Zager 1993), combining the results provided a long-term perspective regarding longevity and dormancy of individual *Lespedeza leptostachya* plants, as well as response to competition and perturbations such as grazing, fire, and drought.

Lifespan and Dormancy of *L. leptostachya*

According to the Prairie Bush Clover Recovery Team (U. S. Fish and Wildlife Service 1988) one of the unknown aspects of *L. leptostachya* is how long individual plants live.

Monitoring of individual plants through-time during this study indicates that the speculation made in the 1988 USFWS Recovery Plan that *L. leptostachya* plants live approximately 10 years may be accurate and appropriate for this population. The age of the monitored *L. leptostachya* was not known at the time they were randomly selected and tagged in 1989. However, by 1995 only 15 plants were present for sampling of 46 remaining tags (Table 1). Four tags of the original 50 could not be relocated during the monitoring period. In fact, when this study was reinitiated in 1993 only 19 plants were available to be sampled. During the seven year study period, at least 31 of the monitored plants died or became dormant (Appendix A).

Precise determination of longevity is made more difficult by the fact that *L. leptostachya* individuals may become dormant. As the mean height of the monitored *L. lepotstachya* plants exceeded 60 cm in each plot in 1989 (Table 1), it is reasonable to assume that Zager and Kern (Zager, Smith, and Kern 1990) selected vigorous adult plants. Smith (1986) reported that wild plants may require 5 or more years to reach maturity. If one assumes that the 50 selected plants were at least 5 years old in 1989, then the loss of over 43% of monitored plants during the next 6 years is not surprising. Furthermore, it might be inferred that 10 years is the approximate life span of plants that are able to reach maturity at Madison Prairie. Certainly there is a possibility that mean longevity is less than 10 years, particularity if mortality in early stages of life is considered. Smith, et al. (2002) indicate that seedling survival averages less than 50% from the first to the second year. In spite of this, they assert that *L. leptostachya* is a long-lived perennial. It may be a question of definitions. However, I would generally not consider 10 years to be a long lifespan for a perennial.

As indicated earlier, *L. leptostachya* has a tendency to become dormant. The Recovery Team (1988) raised the question as to whether certain individual plants in some instances remained dormant in response to environmental or biological stimuli. In an attempt to shed some light on that question, *L. leptostachya* individuals were monitored in this study to assess the hypotheses that dormancy is common in this plant.

During the course of the study, dormancy was commonly observed among monitored *L. leptostachya* plants at Madison Prairie. Monitored individuals in all plots showed an increase in dormancy throughout the study period. During the 1995 growing season, dormancy or death of monitored individuals for all plots exceeded 67% (Table 1, Appendix A). Returning from one year of dormancy was common among monitored individuals in all three plots, it occurred 11 times. However, returning from two successive years of dormancy was very unusual during this study, with only two plants doing so (Appendix A). No monitored individuals reappeared after being listed as dormant for more than two successive years. From this study, it can be assumed that a plant is dead if it does not return from dormancy after two years. Similar to this study, Smith et al. (2002) also found dormancies of one year to be common, with dormancies of two years occurring less frequently. However, they also documented dormancies of up to three years.

One possible explanation for the apparent inability of *L. leptostachya* to survive extended periods of dormancy could be that the relatively small root system and crown may not support such an effort (Klier pers. comm.). This potential influence of a small root and crown may be particularly important for populations at the southern edge of the range where there are approximately three additional weeks of temperatures above 0 degrees Celsius each year, compared to those in Jackson County, Minnesota where Smith et al. (2002) conducted their study. Thus, the longer growing season in southern Iowa compared to southern Minnesota may require that a greater amount of energy reserves be spent in base respiration during dormancy. Another possible rationale, for the differences in dormancies between the two studies is the mean age of the core populations studied by Smith et al (2002) and that of the peripheral population of Madison Prairie. The Recovery Team (1988) noted that preliminary data suggested that the population structure of core populations appeared to be more heavily weighted toward seedlings and juvenile plants whereas peripheral populations appeared to be dominated more by mature plants.

During this study, plants that did not produce flowers were more likely to be dormant the following year than plants that produced flowers/fruit (Tables 4 and 5). This is also consistent with the findings of Smith, et al. (2002). They found that, although transition between size classes for non-flowering individuals was common, plants that flowered tended to remain in the same life stage from year to year. Evidently, plants capable of reproducing in a given year are capable of succeeding in their microenvironment, while those not reproducing have the greatest difficulty in not only reproduction, but in year-to-year survival.

During the 1995 growing season a total of 20 individuals out 1(Table 1, Appendix A) had each been missing for three consecutive years. Since the return of individuals after two years of absence was rare during this study (occurring twice), it can be assumed that these 20 individuals are no longer alive. This represents a minimum 43% loss of monitored *L. leptostachya* plants over a seven year period.

Through the study period, dormancy was more frequent in the ungrazed, burned May 1993 plot than in the grazed plot, and least frequent in the ungrazed, burned April 1990 plot (Appenidix A). If environmental stress in the form of competition, and/or absence of disturbance plays an important role in the dormancy and longevity of *L. leptostachya*, then the more competitive associates (Table 15, Appendix B), and the stable community structure (30 IV rank changes) present in the ungrazed, burned May 1993 plot create more stress on monitored individuals than in the grazed plot (48 IV rank changes), or the less competitive associates and least stable community (44 IV rank changes) in the ungrazed, burned April 1990 plot.

Response of *L. leptostachya* to Fire

During the course of this study, one of the ungrazed plots was burned in April 1990 (NG-BRN90), while the other ungrazed plot was burned May 10, 1993 (NG-BRN93). In a previous study, Selby (1988) reported *L. leptostachya* individuals at Freda Haffner Kettlehole Preserve in Dickinson County, Iowa exhibited an increase in ramet numbers the year of a fire and then returned the next year to their preburn level. Zager (1993) reported similar results in an analysis of data from the 1989 burn in Plot ungrazed, burned 1990 (NG-BRN90) of this study site. However, neither the increase in stem numbers prior to the burn nor the decrease in numbers the next year were significant. The results of the burn in the ungrazed, burned 1993 plot during this study do not confirm these findings (Table 1). As no data was collected in 1992, it cannot be determined that the May 10, 1993 burn caused an increase in stem numbers, and although the stem numbers declined in 1994, the decline was not significant.

Overall, this study did not show consistent or significant results in the response of monitored *L. leptostachya* individuals to fire (Table 1). There was a significant increase in inflorescence height in the ungrazed, burned 1990 plot the year after the burn, but the increase in inflorescence height the year after the burn in ungrazed, burned 1993 plot was not significant. The inflorescence number more than doubled in both of the burn plots the year after the burn, but neither increase was significant. There was a slight increase in plant height after both the 1990 and 1993 burns, but neither was significant (Table 1).

The April 1990 burn at Madison Prairie resulted in a large increase in the mean *L. leptostachya* stem number. However, there was a considerable decrease in mean stem number after the May 1993 fire. These contradictory results may be at least in part due to the differences in seasonal timing between the two burns. Community differences may have also been a factor. The 1990 burn occurred in an apparently healthy *L. leptostachya* population within a disturbed prairie community as evidenced by the high number of IV rank changes (44) and the dominance of forbs by the weedy species *Ambrosia psilostachya* and *Solidago canadensis* (Appendix B). On the other hand, the May 1993 burn occurred in a reduced *L. leptostachya* population during a year of abnormal climatic conditions (Figure 3). The comparatively greater stability of this plot is indicated by the fact that only 30 IV rank changes occurred during the study, whereas the other two plots had 44 and 48 IV rank changes. The burn conducted in 1993 took place in early to mid-May, when many of the warm season plants may have emerged from dormancy. It is possible that the later date of the May 10, 1993 burn in plot NG-BRN93 may have caused different effects than the earlier April 1990 burn in plot NG-BRN90. The effects of fire on monitored individuals in the ungrazed, burned 1993 plot may have been obscured by one or more of the following: increasing forb density throughout the study period, a large decline in the number of monitored plants in the latter years of the study, and a lack of data from the 1992 growing season.

In addition, apparent difference in treatments may be due to sampling error as there was a limited number of replications of treatments in this study.

Due to conflicting results, no conclusive statements can be made regarding the influence of fire on the associate *L. leptostachya*. The May burn apparently had no effect on the mean number of *L. leptostachya* associates in that plot, whereas the April 1990 burn in the other ungrazed plot may have precipitated a decline the following year in the mean number of *L. leptostachya* associates (Tables 1 and 6). The mean number of *L. leptostachya* associates in the ungrazed, burned 1990 plot increased significantly in 1990 after it was burned in April, recording the highest number of associates for all plots, in all years (4.00/m^2) and then declined significantly the following year. At the same time, Importance Values for associate *L. leptostachya* in the ungrazed, burned 1990 plot fell dramatically from 8.8 in 1990 to 2.9 in 1991 (Table 14). Despite the significant influence of the April 1990 fire on the mean number of associate plants, little change was observed in the mean number of *L. leptostachya* associates after the May 1993 fire in the ungrazed, burned 1993 plot. Nor was there a change in the Importance Values (Table 14).

The differences in responses of the Importance Values and the mean number of associate *L. leptostachya* to the two burns may be due to an ineffective late spring burn resulting from abnormal climatic conditions in 1993 (Figure 3) and/or more competition from grass and forb associates in the ungrazed, burned May 10, 1993 plot (Tables 7 and 15).

The results of this study are similar to those of the 11 year study by Smith et al. (2002) which showed that fire had no discernable effect (positive or negative) on *L.*

leptostachya. Bittner and Kleiman (1999) also noted no discernable influence of fire on *L. leptostachya* population trends or seedling establishment and survival. As indicated by Smith et al. (2002), there is a need for future studies specifically designed to test the effects of fire on *L. leptostachya*.

Zager (1993) concluded that *L. leptostachya* benefited from prescribed burning more than from grazing or no disturbance. Selby (1988) also concluded that fire benefited *L. leptostachya*. The results of fire in this study are inconclusive and do not confirm this. However, the results of this study are consistent with the conclusions of Smith, et al.(2002) and Bittner and Kleiman (1999) who found that fire had no conclusive effect on *L. leptostachya*. For these reasons, a more comprehensive study of the influence of fire on *L. leptostachya* is warranted.

Response of *L. leptostachya* to Grazing

The *L. leptostachya* population at Madison Prairie exhibited a dramatic increase in numbers within a short period of time. Dean Roosa and Bill Pusateri observed approximately 200 plants in 1986 and then Scott Zager and Carole Kern documented 3,000 ramets in 1989 (Zager 1993). The 3,000 ramets equates to approximately 2,500 plants, as the average number of stems per plant is 1.2 at Madison Prairie (Table 1).

Light to moderate grazing predominated at Madison Prairie from 1984 to 1989, and a drought occurred in 1988 and 1989. It is possible that either of these factors or a combination of the two may have been responsible for the substantial increase in the *L. leptostachya* population at Madison Prairie. The drought period during the mid- and late

1980's may have favored *L. leptostachya* by weakening competition from associated graminoids and forbs and perhaps created community gaps. Additional study of the effects of grazing was warranted to attempt to determine the effects on populations of *L. leptostachya*. The presence of two cattle exclosures and the use of Madison Prairie for cattle grazing provided an excellent opportunity to study the effects of grazing.

Two exclosures were constructed at Madison Prairie in 1986, so grazing had been excluded from the ungrazed, burned 1990 and ungrazed, burned 1993 plots for three years prior to the first sampling. Table 8 provides a history of grazing of the prairie from 1984-1995. Except for cattle reaching through the exclosure fence and impacting the margins, cattle grazing had been eliminated within the exclosures for nine years by the end of the study period.

In this study, the monitored *L. leptostachya* under grazing showed no statistically significant changes relative to grazing intensity although there were variations in the associate *L. leptostachya* and forbs. The only significant changes in the grazed plot were a decrease in plant height and an increase in inflorescence number from 1989 to 1990 (Table 1). The prairie was subjected to light to moderate grazing both years although rainfall in 1989 was 12.5 centimeters below average. The associate *L. leptostachya* increased significantly in mean number during the second year of light to moderate grazing, and then decreased significantly under moderate to heavy grazing and drier than normal conditions in 1991 (Table 6). The decline in 1991 was dramatic as well as significant, it may have required two years for the associate population of *L. leptostachya* in the grazed plot to recover. In 1993, the mean number of associate *L. leptostachya* had increased even under heavy grazing, but the season was cooler than normal and unusually wet which may have counteracted the effect of the heavier grazing (Table 6). The mean number of associates then declined in 1994, another year of below average rainfall. Moderate to severe grazing in 1991 caused a decline in the mean number of forb stems per quadrat (Table 7), but did not significantly affect the demographic characteristics of the monitored *L. leptostachya* individuals (Table 1).

The demographic data (Appendix A) indicates that monitored individuals in the grazed plot exhibited less dormancy or death than those in the ungrazed, burned 1993 plot that contained more competitive associates, was more stable as evidenced by the least number of IV rank changes of all plots, and showed slightly more dormancy or death than individuals in the ungrazed, burned 1990 plot, which contained the weediest associates of all plots (Appendix B). Overall, evidence of any significant effects of grazing may have been negated by the small sample size resulting from the declining number of monitored *L. leptostachya* throughout the study. The limited number of treatment replications also raises the possibility that sampling error may overshadow differences in treatments.

Overall, the monitoring data from this study on *L. leptostachya* individuals produced no statistically significant results that correlated with grazing intensity. However, it was observed during years of lighter grazing at Madison Prairie that cattle did not select *L. leptostachya* plants. In general, the grass and forb species in the grazed plot that had relatively constant or increased IVs (Tables 11 and 12) were those less palatable to cattle, are clonal (Appendix B), and/or are adapted to frequent, but light, disturbance (*Pycnanthemum virginianum, Aster ericoides, Achillea millefolium, Solidago* *canadensis, Aster oolentangiensis*, and *Euthamia graminifolia*). Some of the species with decreasing IVs and declining rank in IV (*Solidago speciosa, Coreopsis palmata*) are species that tend to be selectively grazed (Weaver 1968) does not list these species as grazing decreasers). Others *(Carex bicknellii, Asclepias verticillata*) may have declined in IV and rank as a result of the increase in moisture and/or increasing competition from tall grasses that followed the drought years of 1988 and 1989 (Zager pers. comm.).

Under a light to moderate grazing regime, *L. Leptostachya* may be benefited more than associate grass and forb species selected by the cattle. This is similar to the observation of Bittner (pers. comm.) at Nachusa Grasslands in Illinois. Weaver (1968) observed a similar positive influence on prairie plants grazed infrequently or avoided by cattle in pasture studies in Iowa and Nebraska. As well, Fahnestock et al. (1994) demonstrated that bison avoidance of *Vernonia baldwinii* and *Ambrosia psilostachya* plants gave them a competitive edge by allowing them to capture a greater amount of sunlight and/or improving air movement around leaves, leading to increased gas exchange and growth rates compared to their associates. In years of more intense grazing, cattle were observed to be more likely to graze *L. leptostachya*. Under grazing, Importance Values of associate *L. leptostachya* remained relatively constant throughout the study period, despite heavier grazing in 1991 and 1993 (Table 8 and 12). Overall, it appears that grazing may benefit *L. leptostachya* by removing competitive associates, creating community gaps, and causing frequent shifts in community composition Tables 11, 12, and 15). Likewise, *L. leptostachya* may not do well in the absence of grazing and when it is in a group of competitive associates. This leads me to speculate that light to moderate grazing of varying levels of intensity and duration may be more favorable for *L. leptostachya* than ungrazed stable prairie communities, or intense grazing although the statistical comparisons in this study did not enable a clear connection to be made between grazing intensity and monitored *L. leptostachya*. In addition, the moisture and/or temperature regime may be involved in the response of *L. leptostachya*, but those effects are more difficult to precisely ascertain.

Schlimgen (1995) attributed the increase in *L. leptostachya* numbers at Westport Drumlin to the drought of 1988 and the presumed weakening of intraspecific [*sic*] competition. Bittner and Kleiman (1999) concluded that the managed improvement of the prairie at Nachusa Grasslands following release from cattle grazing led to an increase in interspecific plant competition that, along with the decrease in soil disturbance, led to a decline in *L. leptostachya* numbers. There is a need for additional long-term studies specifically designed to test the effects of grazing on *L. leptostachya* separate from weather conditions. It is clear that this is very difficult to do under field study conditions.

Influence of Graminoids and Forbs on Monitored *L. leptostachya*

In the ungrazed, burned 1993 plot there were several indications that *L. leptostachya* was subjected to increased competition throughout the study period. These include the following: the dramatic increase in mean forb stems per quadrat (Table 7); greater stability as evidenced by least number of IV rank changes (30) from year to year compared to either the ungrazed, burned 1990 plot (44) or the grazed plot (48) (Tables 9-15, Appendix B); the decrease in IV of forbs that are typically associated with disturbance; the increase in *Andropogon gerardii* and *Sorghastrum nutans*, and the decrease in *Bouteloua curtipendula,* which does not compete well with dense, taller plants (Zager pers. comm., Weaver 1968).

This increased competition appears to have been a greater influence on the *L. leptostachya* in the ungrazed, burned May 1993 plot than in either grazed or ungrazed, burned April 1990 plots (Tables 1, 7,10 and 15). There was a higher rate of dormancy or death among monitored *L. leptostachya* (Tables 4 and 5), fewer associate *L. leptostachya* (Table 6), and generally lower plant height, inflorescence height, and inflorescence number in ungrazed, burned May 1993 plot compared with the other two plots (Tables 1 and 4, Appendix A). The fire of May 10, 1993 may have further increased the competitive pressure on *L. Leptostachya* by stimulating an increase in associated grass and forb species (Tables 7, 9, 10, and 15).

In the grazed plot, Importance Values of associate *L. leptostachya* remained relatively constant throughout the study period, despite heavier grazing in 1991 and 1993. Overall, it appears that grazing may benefit *L. leptostachya* by removing competitive associates, creating community gaps, and shifting community composition. The destabilizing influence of grazing is evidenced by the number of IV rank changes for grasses and forbs (48) in the grazed plot. This was greater than either of the ungrazed plots (NG-BRN93 = 30 and NG-BRN90 = 44). Likewise, *L. leptostachya* may not do well in the absence of grazing and when it is in a group of competitive associates. Although statistical comparisons in this study did not enable a clear connection to be made between grazing intensity and monitored *L. leptostachya.* This is at least partly due to the small number of individuals sampled, making it difficult to reach the threshold of statistical significance.

Many forb species in the ungrazed, burned April 1990 plot demonstrated more annual fluctuation in IV numbers, as well as more IV rank changes (44) than the other ungrazed plot (30), which would tend to indicate a less stable community (Tables 13, 14 and 15). The majority of species that were IV decreasers are weedy species typical of disturbed prairie areas (*Ambrosia psilostachya, Carex bicknellii, Vernonia baldwinii, Solidago canadensis*, and *Asclepias verticillata*) (Zager pers. comm., Appendix B). Along with the dominant forb species that increased in IV (*Aster ericoides, Aster oolentangiensis, Pycnanthemum virginianum*), these changes would tend to indicate that the community is becoming more stable (Table 14).

The fire in April 1990 may have created gaps in the community that *Poa pratensis* could colonize. Between 1990 and 1994, the decreases in IV of *Poa pratensis* and *Bouteloua curtipendula*, with a concurrent rise in IV of the competitive species *Andropogon gerardii* and *Sorghastrum nutans* (Appendix B) tend to indicate a more competitive situation as the tall grasses became more dominant. This change in grass species dominance is similar to one that Weaver (1968) documented in prairies of Iowa and Nebraska as they recovered from the drought of the 1930's.

In spite of these trends, the ungrazed, burned April 1990 plot had the greatest IV fluctuations of the two ungrazed plots. In 1994, the dominant forbs were still composed of weedy species (Appendix B) typical of disturbed areas, including the top two ranked forbs, *Ambrosia psilostachya* and *Solidago Canadensis*. This indicates that the community in this plot is the least stable of the two ungrazed plots.

A number of associate graminoids and forbs displayed similar patterns in all monitored plots. The associates that were increasers in all plots include the competitive species *Aster ericoides, Anemone cylindrica, Ratibida pinnata, Sorghastrum* nutans, and *Andropogon gerardii* (Appendix B). Species with decreasing IV's in all three plots include *Lespedeza leptostachya, Carex bicknellii*(which disappeared in 2 plots), *Asclepias verticillata*(disappeared in all 3 plots) and *Bouteloua curtipendula.* Of these, *Carex bicknellii, Asclepias verticillata,* and *Bouteloua curtipendula* can be characterized as weak competitors and gap opportunists with the ability to capitalize on disturbance or environmental stress, particularly on droughty soils (Zager pers. comm.).

Within the ungrazed, burned May 1993 plot, eight of the ten highest ranking forbs are generally considered to have competitive characteristics (Betz 1984, Schram 1976, 1992, and Weaver 1968) and/or be clonal (Gleason and Cronquist 1991). In different years in the grazed and ungrazed, burned April 1990 plots, six to seven of the top ten ranking forbs were competitive and/or clonal (Table 15). Across the years, the highest ranking forbs in all three plots tend to be considered to be at least moderately competitive (Betz 1984, Schram 1976, 1992, and Weaver 1968) and/or have clonal growth habits (Gleason and Cronquist 1991).

There was a dramatic increase in the average number of forb stems in the ungrazed, burned 1993 plot from 74 in 1989, to 193 in 1993, with a slight decrease to 143 in 1994 (Table 7). By comparison, the other two plots had 55 and 69 forb stems per quadrat in 1989, with a range of 54 to 84 forb stems per quadrat in 1993 and 1994. Despite the similar increase in forb stem density in the two ungrazed pots (increasing 2.3 times between the year prior to a burn and the burn year) the ungrazed, burned 1990 plot returned to near preburn forb stem density levels. However, the ungrazed, burned 1993 plot retained elevated forb stem density the year after it was burned that were approximately two times higher than either of the other plots. Overall, the dramatic rise in forb stems in the ungrazed, burned 1993 plot throughout the study period contributed to an increase in competition for nutrients and available moisture.

The increase of *Poa pratensis* in all plots during the years of 1990 and 1991 may represent a rapid expansion of its influence in the early stages of drought recovery as more moisture became available. *Poa pratensis* then had a reduction in IV as the taller, more dominant native grasses *(Andropogon gerardii* and *Sorghastrum nutans*) gained an edge in obtaining light, water, and nutrients.

The greater availability of moisture in the latter part of the study, the short-term increase of *Poa pratensis,* as well as the long-term increase of the competitive species *Sorghastrum nutans* and *Andropogon gerardii* (Appendix B) tends to indicate recovery from a drought period. As previously mentioned, this is similar to a change in species composition that Weaver (1968) documented in prairies of Iowa and Nebraska as they recovered from the drought period of the 1930's. This general trend in all of the plots lends support to the possibility during the study the prairie was recovering from the drought years of 1988-89.

This possiblity is consistent with the assertions of Schlimgen (1995), and Bittner and Kleiman(1999). Schlimgen attributed the increase in *L. leptostachya* numbers at Westport Drumlin to the drought of 1988 and the presumed weakening of intraspecific [*sic*] competition. Bittner and Kleimann (1999) concluded that the managed improvement of the prairie at Nachusa Grasslands following release from cattle grazing led to an increase in interspecific plant competition that, along with the decrease in soil disturbance, led to a decline in *L. leptostachya* numbers.

Importance Values for associate *L. leptostachya* in the ungrazed, burned 1990 plot remained relatively constant from 1989 to 1990, then fell dramatically, from 8.8 in 1990 to 2.9 in 1991. They rebounded to 8.2 in 1993, followed by a fall to 4.4 in 1994. Overall, the apparently less competitive community in the ungrazed, burned 1990 plot may have enabled the monitored *L. leptostachya* to maintain a higher Importance Value in that plot during the latter years of the study. Conversely, the apparently increasingly competitive associates in the ungrazed, burned May 1993 plot (Tables 7, 9, and 10), and the increasing grazing pressure (Table 8) in the grazed plot during the study may have caused the decreases in Importance Values in those plots. Overall, the number of associate *L. leptostachya* declined during the course of the study in the ungrazed, burned April 1990 plot, to approximately one half of their 1989 levels (Table 6). Within Plot 1, eight of the ten highest ranking forbs are generally considered to have competitive characteristics and/or be clonal (Table 15, Appendix B). In different years in the grazed plot and the ungrazed, burned 1990 plot, six to seven of the top ten ranking forbs are competitive and/or clonal.

If stress in the form of competition has an important influence on *L. leptostachya*, then the more competitive associates (Table 15), and the stable community structure (30 IV rank changes) present in the ungrazed, burned May 1993 plot create more stress on monitored individuals than in either the grazed plot (48 IV rank changes), or the less competitive associates and least stable community (44 IV rank changes) in the ungrazed, burned April 1990 plot (Table 15, Appendix B). The ungrazed, burned 1993 plot with more competitive associates had the highest rates of *L. leptostachya* dormancy or death of the three plots in the study (Tables 4 and 5, Appendix A). Conversely, the ungrazed, burned 1990 plot dominated by more weedy species and with fewer competitive species compared to the ungrazed, burned 1993 plot had the lowest rate of dormancy or death among the three plots (Tables 4 and 5, Appendix A). This suggests that *L. leptostachya* does not fare well in competitive situations.

As discussed earlier, light to moderate grazing appears to benefit *L. leptostachya* at least in part by removing competitive associates and creating community gaps. The destabilizing influence of grazing on community composition is evidenced by the highest number of IV rank changes of all plots (48). The monitored *L. leptostachya* in the grazed plot exhibited a dormancy and death rate closer to that of the weedier, less competitive plot than the ungrazed, burned 1993 plot with more competitive associates. *Lespedeza leptostachya* appears to be at least as importantly influenced by competitive associates as by fire or grazing, neither of which conclusively benefited *L. leptostachya* during this study. Also, as this study progressed, it became apparent that there is a need for additional research to more definitively determine competitiveness among species of prairie plants.

CHAPTER 5

CONCLUSION

The study yielded the following conclusions regarding *Lespedeza leptostachya* at the Madison Prairie:

- *Lespedeza leptostachya* is a short-lived perennial as indicated by the loss of 21 of 46 of the monitored plants in a six-year period.
- A one year dormancy period is common in *Lespedeza leptostachya* although two consecutive years of dormancy is rare.
- No pattern of influence of fire on *Lespedeza leptostachya* could be discerned due to conflicting results.
- No statistically significant effect of cattle grazing on *Lespedeza leptostachya* was observed although under light moderate grazing, it was not selected by cattle and appeared to be benefited by removal of competitive associates, creation of community gaps, and shifts in community composition.
- Apparently *Lespedeza leptostachya* does not fare well in competitive situations as the plot with the most stable prairie community showed the highest rates *L. leptostachya* dormancy and death.

At Madison Prairie, *Lespedza leptostachya* exhibits the characteristics of a somewhat short-lived perennial, as shown by the large number of monitored individuals presumed to be dead after the seven year course of this study. At Madison Prairie *L. leptostachya* individuals may remain dormant for one growing season, but seldom longer than that.

During the course of this study, the plot with the greatest competition from other prairie species and the most stable community showed the highest rates of *L. leptostachya* dormancy or death. Conversely, the plot with the least competitive group of species had the lowest rate of dormancy or death. This suggests that *L. leptostachya* does not fare well in competitive situations. *L. leptostachya* was not conclusively benefited by fire or grazing during this study, and appears to be at least as importantly influenced by competitive associates.

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APPENDIX A – DEMOGRAPHIC FIELD DATA

Plot 1 - data for plants present

	stem number						plant height						infloresence height						Infloresence number						life stage					
Tag #	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995
901	1	mt	mt	mt	mt	mt	92	mt	mt	mt	mt	mt	25	mt	mt	mt	mt	mt	27	mt	mt	mt	mt	mt	3	mt	mt	mt	mt	mt
902	2	1	mt	mt	mt	mt	100	25	mt	mt	mt	mt	48	0	mt	mt	mt	mt	20	0	mt	mt	mt	mt	3	0	mt	mt	mt	mt
903	1	1	1	2	2	2	42	75	NP	59.4	65	53.9	5	36	13	12.6	0	6	2	9	6	7	0	3	3	4	2	4	2	3
904	1	1	3	NP	NP	NP	74	50	48	NP	NP	NP	32	0	0	NP	NP	NP	16	0	0	NP	NP	NP	3	1	1	0	0	0
905	2	1	2	1	NP	1	57	30	21	38.5	NP	39	16	0	0	0	NP	0	9	0	0	0	NP	0	3	1	1	2	0	2
906	1	1	NP	1	NP	NP	51	27	21	30.5	NP	NP	0	0	NP	0.6	NP	NP	0	0	NP	1	NP	NP	2	1	0	3	0	0
907	1	1	NP	NP	NP	NP	48	68	NP	NP	NP	NP	11	16	NP	NP	NP	NP	5	0	NP	NP	NP	NP	2	3	0	0	0	0
908	1	1	1	2	1	1	35	73	33	58.2	43.2	69.4	2	20	0	11.9	0	23	3	27	0	6	0	7	2	4	1	3	2	4
909	1	1	1	1	NP	NP	57	67	72	28.5	NP	NP	7	23	29	0.5	NP	NP	6	24	18	1	NP	NP	2	3	2	3	0	0
910	2	1	NP	NP	NP	NP	69	5	NP	NP	NP	NP	28	0	NP	NP	NP	NP	10	0	NP	NP	NP	NP	2	1	0	0	0	0
911	1	1	1	NP	NP	NP	83	21	16	NP	NP	NP	38	0	0	NP	NP	NP	46	0	0	NP	NP	NP	3	1	1	0	0	0
912	1	NP	1	NP	1	1	42	80	16	NP	34.6	37	3	37	50	NP	0	0	2	39	22	NP	0	0	2	4	4	0	1	2
913	1	1	1	1	1	1	88	81	94	39.6	57.4	36.7	27	46	0	1.3	31	0	43	33	0	1	4	0	3	4	1	3	4	2
914	1	NP	1	NP	NP	NP	82	NP	22	NP	NP	NP	34	NP	0	NP	NP	NP	40	NP	0	NP	NP	NP	3	0	2	0	0	0
915	1	1	NP	NP	NP	NP	28	60	NP	NP	NP	NP	0	12	NP	NP	NP	NP	0	19	NP	NP	NP	NP	2	3	NP	0	0	0
916	1	1	NP	2	1	NP	58	75	NP	26.4	26.1	NP	11	30	NP	4.7	0	NP	7	9	NP	2	0	NP	3	4	0	3	1	0
917	1	1	1	1	NP	NP	78	20	17	24.2	NP	NP	19	0	0	0	NP	NP	13	0	4	0	NP	NP	2	1	1	2	0	0
918	1	1	1	1	NP	NP	20	70	62	43.6	NP	NP	0	37	13	0	NP	NP	0	14	0	0	NP	NP	2	4	2	2	0	0
919	2	1	NP	NP	NP	NP	67	NP	NP	NP	NP	NP	12	NP	NP	NP	NP	NP	17	NP	NP	NP	NP	NP	3	4	0	0	0	0
920	1	1	mt	mt	mt	mt	60	93	mt	mt	mt	mt	10	21	mt	mt	mt	mt	8	9	mt	mt	mt	mt	3	0	mt	mt	mt	mt

NP - no data, plant not present

mt - missing tag

PLOT 2 -data for plants present																														
stem number							plant height						infloresence height						infloresence number						life stage					
Tag #	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995
922	1	1	1	NP	NP	NP	43	26	8	NP	NP	NP	0	0	0	NP	NP	NP	4	0	0	NP	NP	NP	2	2	2	0	0	0
923	2	NP	NP	NP	NP	NP	67	NP	NP	NP	NP	NP	0	NP	NP	NP	NP	NP	12	NP	NP	NP	NP	NP	3	0	0	0	0	0
924	1	1	2	NP	NP	NP	87	12	15	NP	NP	NP	0	0	0	NP	NP	NP	32	0	0	NP	NP	NP	3	2	2	0	0	0
925	1	1	1	NP	NP	NP	44	55	56	NP	NP	NP	27	27	26	NP	NP	NP	5	14	18	NP	NP	NP	2	4	4	0	0	0
926	1	1	1	NP	NP	NP	70	81	78	NP	NP	NP	52	52	25	NP	NP	NP	7	21	25	NP	NP	NP	3	4	3	0	0	0
927	1	1	2	1	NP	1	74	62	64	43.9	NP	72.6	29	29	20	14.9	NP	41.5	33	40	18	8	NP	20	3	4	4	4	0	4
928	1	1	1	1	1	2	54	20	58	63	57.8	54.7	0	0	25	37.8	11	0	8	0	18	25	2	0	2	1	4	4	4	2
929	1	2	1	NP	1	1	38	29	6	NP	36	63.4	0	0	0	NP	0	1	3	0	0	NP	0	1	2	2	2	0	2	3
930	1	1	4	1	NP	1	69	62	30	9.3	NP	42.2	15	15	5	0	NP	13.1	32	3	5	0	NP	6	3	3	3	3	0	4
931	1	1	1	2	1	2	61	55	72	32.6	58.4	51.8	14	14	20	0	25.2	6.7	5	6	18	0	9	3	2	4	3	0	4	4
932	1	1	NP	NP	NP	NP	37	20	NP	NP	NP	NP	0	0	NP	NP	NP	NP	2	0	NP	NP	NP	NP	2	2	0	0	0	0
933	1	1	1	NP	NP	1	54	36	25	NP	NP	43.3	0	0	0	NP	NP	3.4	5	0	0	NP	NP	1	2	2	2	0	0	3
934	1	1	NP	NP	NP	NP	71	15	NP	NP	NP	NP	0	0	NP	NP	NP	NP	33	0	NP	NP	NP	NP	3	1	0	0	0	0
935	1	1	2	NP	2	NP	58	15	48	NP	41.2	NP	0	0	11	NP	22.4	NP	26	0	9	NP	8	NP	3	1	3	0	4	0
936	1	1	1	NP	NP	NP	79	33	30	NP	NP	NP	21	21	10	NP	NP	NP	31	7	5	NP	NP	NP	3	4	3	0	0	0

NP - no data, plant not present

mt - missing tag

	PLOT 3 - data for plants present																													
	stem number						plant height						infloresence height						infloresence #						life stage					
Tag#	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995	1989	1990	1991	1993	1994	1995
939	2	1	1	2	1	1	61	70	76	43	54	79.6	14	34	41	0	2	35.8	7	21	45	0	1	4	2	4	3	3	4	4
940	1	1	1	mt	mt	mt	57	55	87	mt	mt	mt	7	0	49	mt	mt	mt	3	0	3	mt	mt	mt	2	2	2	mt	mt	mt
941	1	1	1	NP	NP	NP	56	68	3	NP	NP	NP	15	0	0	NP	NP	NP	11	0	0	NP	NP	NP	3	2	1	0	0	0
942	1	1	NP	NP	NP	NP	64	43	NP	NP	NP	NP	21	0	NP	NP	NP	NP	26	0	NP	NP	NP	NP	3	2	0	0	0	0
943	1	NP	NP	NP	NP	NP	61	NP	NP	NP	NP	NP	0	NP	NP	NP	NP	NP	0	NP	NP	NP	NP	NP	2	0	0	0	0	0
944	1	NP	1	NP	1	NP	52	NP	18	NP	34.7	NP	0	NP	0	NP	0	NP	0	NP	0	NP	1	NP	2	0	1	0	1	0
945	2	2	1	1	1	1	65	43	72	40.6	45.8	49.9	12	0	19	1.1	0	4	9	0	11	1	1	1	2	2	2	3	2	3
946	1	4	2	1	1	1	93	61	76	81.1	74.1	62.2	49	18	30	23.2	5.4	18.7	68	3	43	14	1	4	2	4	3	4	3	4
947	2	2	1	1	3	NP	84	100	92	61.2	66.6	NP	45	55	48	20.9	1.4	NP	49	46	42	5	3	NP	3	4	3	4	3	0
948	1	1	1	1	2	NP	76	96	103	78.2	46.6	NP	38	44	73	29	5.6	NP	15	28	58	12	2	NP	2	4	3	4	3	0
949	2	3	1	NP	NP	NP	81	45	72	NP	NP	NP	39	0	38	NP	NP	NP	30	0	73	NP	NP	NP	3	2	3	0	0	0
950	1	2	2	NP	NP	NP	89	78	79	NP	NP	NP	49	26	42	NP	NP	NP	59	24	34	NP	NP	NP	4	4	3	0	0	0
951	1	1	1	NP	1	NP	75	68	53	NP	18.6	NP	16	36	18	NP	0	NP	11	19	7	NP	1	NP	3	4	3	0	1	0
952	2	2	2	NP	NP	NP	38	57	70	70.1	NP	NP	28	3	26	NP	NP	NP	2	14	22	NP	NP	NP	4	4	3	0	0	0
953	1	2	2	2	1	1	70	70	89	NP	64.3	109.2	36	34	48	30.2	25.3	44.6	44	26	72	10	1	48		4	3	4	4	4
NP - no data, plant not present																														
mt - missing tag																														

APPENDIX B – COMPETITIVE SPECIES CHARACTERIZATION SUMMARY

Appendix B: Characterization of species according to Betz, Schram, Weaver, and Gleason and Cronquist, for highest Importance Value Ranked species in study plots.

Species	**Characterization***			
	Betz[1]	Schram[2]	Weaver[3]	Gleason & Cronquist[4]
Achillea millefolium	-	-	*GI*	*R*
Ambrosia psilostachya	-	-	GI	R
Amorpha canescens	less competitive	-	GD	-
Anemone cylindrica	-	moderate	-	-
Asclepias verticillata	-	-	-	-
Aster ericoides	less competitive	good	C, GI	R
Aster oolentangiensis	less competitive	moderate	-	R
Aster pilosus	-	-	-	-
Brickellia eupatoroides	-	-	C	-
Carex bicknellii	-	-	-	R
Coreopsis palmata	competitive	good (may be allelopathic)	-	R
Dalea candida	less competitive	-	GD	-
Euthamia graminifolia	competitive	-	-	-
Heliopsis helianthoides	-	good	-	-
Heuchera richardsonii	-	-	-	-
Lespedeza capitata	-	very good	GD	-
Lespedeza leptostachya	-	-	-	-
Lithospermum canescens	-	low	-	-
Lysimachia ciliata	-	-	-	R
Malus ioensis	-	-	-	-
Physalis heterophylla	-	-	-	R
Potentilla arguta	-	-	-	-
Pycnanthemum virginianum	less competitive	medium	-	-
Ratibida pinnata	competitive	aggressive	-	-
Rosa spp.	-	medium	-	C
Ruellia humilis	-	-	-	-
Senecio spp.	-	-	-	R
Solidago canadensis	weedy	weedy	-	R
Solidago speciosa	-	-	-	-
Symphoricarpos orbiculatus	-	-	-	-
Viola pedatifida	-	-	-	-
Grasses		-	-	
Andropogon gerardii	competitive	competitive	C, GD,	r
Bouteloua curtipendula	-	-	O, GI	-
Poa pratensis	-	-	O, GI	R
Schizachyrium scoparium	-	-	GD	-
Sorghastrum nutans	competitive	-	GD	r
Sporobolous heterolepis	less competitive	-	GD	-

* Species characterized according to Betz (1984), Schram (1976, 1992), and Weaver (1968)

[1] Betz termed species that established well in weedy prairie plantings, or the last species to disappear as prairie is degraded, as "competitive" or as having "competitive ability", and those that establish well after an initial phase as "less competitive".

[2] Schram characterized species as having "competitive ability" in prairie plantings defined as "low", "moderate", "good" "very good", and "aggressive" based on observations of prairie restoration plantings into crop fields in western Illinois.

[3] C=competitive, O=opportunist, GD=grazing decreaser, GI=grazing increaser

[4] Listed in Gleason and Cronquist (1991) as R=rhizomatous, C=colonial, r=shortly rhizomatous