July 1, 2002

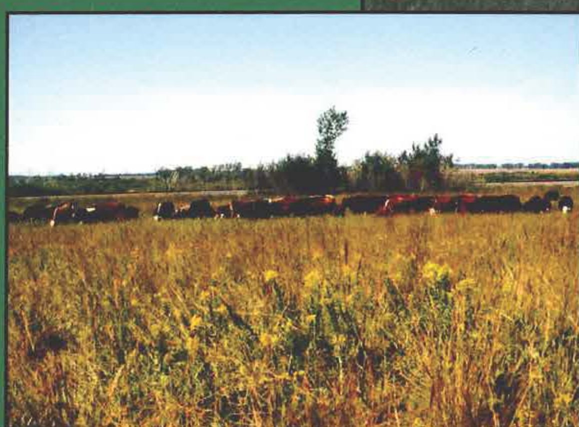
LCMR Final Program Report

LCMR Work Program 1999

PROJECT TITLE:

INTEGRATED PRAIRIE MANAGEMENT

Ch. 231, Sec. 16 Sub. 7 d -
(Agricultural and Natural Resources Based Industries)



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8 August 2002

John Velin, Director
Legislative Commission on Minnesota's Resources
100 Constitution Avenue
Room 65, State Office Building
Saint Paul, MN 55155

Dear Mr. Velin:

I am enclosing 3 copies of the final report for the project, **INTEGRATED PRAIRIE MANAGEMENT, Ch. 231, Sec. 16, Sub. 7 d.**

I have also included copies of the following reports that were part of the project:

1. ***Felton Prairie Stewardship Plan***
2. ***Landowner's Guide To Prairie Management In Minnesota***. These are prepublication copies and final copies will be available by 15 August for wide distribution.

Another report entitled, ***Aggregate Resource Evaluation***, was completed earlier and has been delivered to your office.

Thank you and please advise if you have any questions. Things have gone well on the project and thanks for the support and helpfulness of you and your staff.

Sincerely,

W. Daniel Svedarsky, Project Manager

cc. Margaret Kuchenreuther, Greg Cuomo, Tim Magnusson, Cindy Buttleman, Peter Buesseler, Larry Smith

July 1, 2002

LCMR Final Program Report

Project Completion Date: 30 June 2002

LCMR WORK PROGRAM 1999

I. PROJECT TITLE: Ch. 231, Sec. 16, Sub. 7 d ---- INTEGRATED PRAIRIE MANAGEMENT

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TOTAL BIENNIAL PROJECT BUDGET:

$ LCMR:	350,000	$ Match:	(none required)
- $ LCMR Spent	327,074		
$ LCMR Balance	22,926		

A. LEGAL CITATION: ML 1999, Chap. 231, Sec. 16, Subd. 7d (Agriculture and Natural Resource Based Industries) INTEGRATED RESOURCE MANAGEMENT.

Appropriation Language:

$ 175,000 the first year and $ 175,000 the second year are from the trust fund to the Commissioner of Natural Resources for an agreement with the University of Minnesota and Clay County in a cooperative project for an aggregate resource inventory on public lands, prairie restoration and research, and stewardship plans for management options. This appropriation is available until June 30, 2002 at which time the project must be completed and final products delivered, unless an earlier date is specified in the work program.

B. STATUS OF MATCH REQUIREMENT: (None required)

II. and III. PROGRESS SUMMARY:

This project was made up of 2 subprojects. The first examined challenges of conserving prairie in the Felton Prairie Complex of Clay County where it overlies valuable aggregate resources. This included, 1) an aggregate inventory using rotosonic drilling, 2) the reclamation of an abandoned gravel pit to a wetland and prairie reconstruction to provide a place for public interpretation of the Felton Prairie Complex and adjacent gravel mining activities, and 3) integrated stewardship planning. A site-specific stewardship plan was developed for about 2,000 acres of public land within the Complex with emphasis on developing a conflict resolution process for the 800 acres containing both prairie and gravel. The process recognized society's interest in prairie conservation as well as the need for aggregate resources. The second part of the project researched management effects of fire and grazing on prairie vegetation and grassland birds, and the use of prairie vegetation by livestock at selected sites in a 9-10 county area, including Clay County. Rotational grazing contributed to the maintenance of desirable prairie plants more than continuous grazing or no grazing. In spite of a short study period, prescribed burning increased desirable prairie plants over no-burn controls. The post-burn age of prairie plots affected birds differently depending on their habitat requirements, emphasizing the need for a mosaic of post-burn ages of prairie management units in the landscape. Prairie vegetation can provide desirable livestock forage during the warm part of the grazing season since many native grasses grow best then. Moderately-grazed prairie contained more birds that either heavily grazed or lightly-grazed plots. A landowner's guide to prairie management was prepared and will be widely distributed to individuals and agency prairie managers. It contains finding of this study and other research which is applicable to native prairie management and planting prairie in aggregate-mined areas.

IV. OUTLINE OF PROJECT RESULTS.

A. Subproject One – FELTON PRAIRIE STEWARDSHIP PLAN FOR PUBLIC LANDS

Result 1. Aggregate resource inventory on selected public lands (Cindy Buttleman, Leader).

A targeted drilling program on selected public lands was completed in January 2000. Using rotosonic drilling methods, 27 holes were drilled within a 735-acre target area on Felton Prairie for a total of 2,059 linear feet ranging in depth from 25 to 145 feet. From this information, geologic interpretations were developed about the aggregate resource and volume estimates were calculated. The report was completed in May 2000 and delivered to the Felton Prairie Stewardship Committee. The report contains detailed maps, cross-sections, sample analyses, and volumetric calculations describing the quality and quantity of aggregate resources on selected public lands in the Felton Prairie Complex. The drilling was completed under the supervision of professional staff from the DNR Division of Lands & Minerals. DNR interpreted the data and prepared the final report. Mn/DOT staff performed laboratory analysis on the collected samples. Had this result not been completed, future decisions on the stewardship of public lands would have been based on opinion, supposition, and guesses as to the precise extent of the aggregate resource at Felton Prairie. By using the rotosonic inventory data, the Stewardship Committee was able to bring all parties involved to a consensus as to the aggregate resource present in the study area. Without such a consensus, getting all parties to agree on future stewardship practices for the area would have been very difficult if not impossible. In hindsight, no procedural changes would have been made. Result 1 was successfully accomplished and the report was forwarded to LCMR. The budget for this result was expended and no balance remains.

LCMR BUDGET: 95,000
BALANCE: 0

Result 2. Prairie restoration/gravel pit reclamation (Cindy Buttleman, Leader).

Using aggregate resource information generated from Result 1 and other existing resource information, the Stewardship Committee selected a depleted gravel-mining site on public land known as the "Zilmer Pit" for reclamation. Earthwork was completed in the spring of 2001. Surplus rock from the site was used for 3 DNR stream restoration projects. A parking area was installed that includes 5 interpretative signs (see photo page). Additional funds for the project were provided by Clay County through proceeds from the Aggregate Material Tax. Project partners included the aggregate industry (Aggregate Industries, Northern Improvement, Turner Sand & Gravel, Selin Brothers, Inc.), The Nature Conservancy, U.S. Fish & Wildlife Service, Clay County, MN DNR, Minnesota Conservation Corps, and Ameri-Corp. Seeding of the site with native prairie vegetation was completed in the spring of 2002. This project provided a parking area and vantage point for the public to safely view the Felton Prairie area. Interpretative signs explain the values of both gravel and prairie, and the history of Felton Prairie. This will be the first gravel pit reclamation project on public land in the Felton Prairie area and will serve as an impetus for other reclamation work. This result is significant because it demonstrates how a variety of players, both public and private, can be brought together to restore and reclaim prairie and mining sites located on public land. It also provides the citizens of Minnesota with a gravel/prairie interpretive site that was previously unavailable. This site will be used by the general public and educational institutions, from elementary through college level, to teach students how competing interests -- prairie conservation and gravel mining -- can co-exist more harmoniously and apply integrated land management. The project was completed and the budget was completely expended.

LCMR BUDGET: 35,000
BALANCE : 0

Result 3. Stewardship plan for public land on Felton Prairie (Tim Magnusson, Leader).

Work on the Stewardship Plan final draft was completed in late April, 2002 by Alison Krohn, Landscape Architect at North Dakota State University. The plan considered provisions for gravel mining, gravel pit reclamation, prairie conservation, and prairie restoration. Inventory drilling data from Result 1, which delineated gravel quantity and quality, provided a basis for identifying areas of high conflict (good prairie, good gravel) and low conflict (good prairie, limited gravel) and also helped determine what stewardship method would be applicable for each area. The Stewardship Committee held approximately 32 meetings to discuss methods and elements of the stewardship plan. Publicly-owned tracts were identified where natural values are such to preclude gravel mining and others where mining would be the most appropriate use. The Committee reviewed results of a DNR fen habitat study conducted in the area in order to determine the impact said study would have on the final stewardship plan and deep aggregate mining proposed in the Felton Prairie area. This integrated stewardship plan is significant because it is, to the best of our knowledge, the first of its kind in Minnesota. It was developed by a committee whose membership contained aggregate industry representatives, conservationists, local jurisdiction staff and elected officials, and representatives of state and federal agencies. What resulted was a stewardship plan that addressed the primary interests and concerns of all parties involved. It is hoped that the process followed by the Felton Prairie Stewardship Committee can be adapted across the state of Minnesota when an array of conflict issues are encountered. The Plan will also be used in migation by Clay County for a MN DNR Special Taking Permit necessary to allow the County to expand its current gravel mining operation in the Felton Prairie area. This work benefited all Minnesotans by providing a blueprint for preservation of one of the most significant prairie areas left in the state. It provided the MN DNR and other conservation groups with data necessary to consider acquisition of some portions of the Felton Prairie area by the Scientific and Natural Area program or The Nature Conservancy. Clay County benefited from this project by learning the full extent of aggregate resources and by being able to continue its aggregate mining operations in the Felton Prairie area with minimal impact to the adjacent prairie and natural areas.

After approval by the Stewardship Committee, a final draft of the Plan was presented to the Clay County Board of Commissioners where it was formally adopted on 21 May 2002. Due to the Committee's ability to contract for consulting services through North Dakota State University, costs for such services were greatly reduced and a balance of $11,249 remains.

LCMR BUDGET: 62,308
BALANCE: 11,249

Entrance and parking area for Zilmer Pit Reclamation Project (above) and example of signage used in the area (below).

B. Subproject Two – EFFECTS OF FIRE AND GRAZING ON PRAIRIE VEGETATION, LIVESTOCK, AND BIRDS IN WESTERN MINNESOTA

Result 1. Fire and grazing effects on prairie vegetation (Margaret Kuchenreuther, Leader).

Four cooperators who have each implemented different types of grazing systems on native prairie were identified to participate in this on-farm study. Grazing systems on the properties ranged from ungrazed to season-long grazing to rotational grazing using 3 to 10 paddocks. In August 1999, 6 permanent plots for vegetation measurements were established in native pastures on each farm (with the exception of the Dean Elmer farm where experimental manipulations were planned; there 6 plots were established in each of 2 grazed and 2 ungrazed paddocks). Each plot was sampled to record the frequency of a list of 51 indicator taxa. Relative basal cover of native grasses, introduced grasses, forbs, woody plants, rocks, litter, and bare ground also were recorded. All sampling was done so it could be repeated in the same locations in following years. These measurements were repeated during the 2000 and 2001 growing seasons.

At the end of the 1999 growing season, 3 fenced exclosures were built in each of 4 paddocks on the Elmer farm in 2 of 10 rotationally-grazed paddocks and in 2 ungrazed paddocks. We originally intended to burn 1 of the grazed and 1 of the ungrazed paddock and then introduce grazing into the 2 formerly ungrazed paddocks. However, our plans changed when we were unable to obtain permission to begin grazing the ungrazed paddocks because they had been enrolled in the CRP program during the first year of the study. Instead, we burned half of the plots in the ungrazed paddocks at the Elmer farm in May 2001. Subsequently, we repeated the measurements noted above, as well as assessing the effects of fire on woody vegetation in the plots by scoring each woody stem as healthy, dead or sprout.

Additionally, in summer 2000 we clipped biomass at the Elmer farm several times during the growing season both inside and outside of the exclosures and in the ungrazed paddocks to estimate forage production and forage quality. The forage production samples were sent out for analysis but an inexplicable and serious error on the part of the contractor rendered most of the data unusable. Therefore, we have no results to report for this part of the project.

<u>Effects of grazing rotation system on prairie vegetation</u>

Several important trends associated with grazing system were observed. The farms with the shortest rotations (i.e., rotation through the largest number of paddocks) had significantly lower frequencies of the annual weeds, plumeless thistle (*Carduus acanthoides*), foxtail (*Setaria* spp.) and prostrate spurge (*Euphorbia* sp.), and of the perennial exotic species, smooth brome grass (*Bromus inermis*), than farms with the longest grazing rotations. Of particular note is the continuously-grazed pasture, which had a serious thistle infestation

(43.7 % of the quadrats sampled contained one or more thistles). In contrast, the farm with a 3-paddock rotation had the lowest frequency of thistles (only 3.9%), perhaps as a result of its low relative cover value for bare ground (~ 10%). Other clear trends were seen in the frequency of the native legume, leadplant (*Amorpha canescens*), which significantly increased in frequency as paddock number increased, and the frequency of the native grass, sideoats grama (*Bouteloua curtipendula*), which decreased in frequency as paddock number increased. No other large-scale differences in taxon richness, taxon frequency or vegetative cover were found on farms studied.

The general conclusions of this part of the study correspond with the results of studies of grazing systems in other parts of the tallgrass prairie, which have found little effect of grazing regime on standing crop or on the dominance of broad vegetation categories, such as tall grasses, mid-grasses and forbs. However, the results of this study should raise concerns about the efficacy of continuous grazing in native prairies, as it appears to promote high frequencies of noxious weeds and the reduced frequency of desirable native legumes, compared to prairies that are rotationally grazed.

Effects of experimental manipulations

The results of this part of the study compared vegetation in plots exposed to long-term rapid rotational grazing, similarly grazed plots from which cattle were excluded in 2000 and 2001, long-term ungrazed plots, and long-term ungrazed plots that were burned in 2001.

The number of forb taxa was somewhat lower in the ungrazed plots than grazed plots (26-27 vs. 23-24). The application of fire increased the number of forbs decreased by grazing relative to the number seen before the burn (5 taxa pre-burn vs. 8 post-burn). However, release from grazing resulted in no significant change in the number of forb taxa counted.

Long-term grazed paddocks had greater frequencies of some weedy taxa (*Euphorbia* and *Setaria* spp.) as well as rossette-forming species (*Geum triflorum* and *Antennaria* sp.), the native grama grasses (Bouteloua spp.), and junegrass (*Koleria cristata*) than ungrazed paddocks. The high frequency of weedy species is likely a result of the high proportion of bare ground measured in grazed paddocks (26-35%) versus ungrazed paddocks (5-9%). Long-term ungrazed paddocks had higher frequencies of the native forbs, frost aster (*Aster ericoides*) and ground cherry (*Physalis* spp.), native grass prairie dropseed (*Sporobolus heterolepis*) and the non-native grass, smooth brome grass.

Release from grazing caused few measurable changes in plant frequency. Establishment of exclosures resulted in a small increase the frequency of leadplant and a 1 year increase in the frequency of flax (*Linum* sp.). It reduced the frequency of prostrate spurge and eliminated non-native foxtail species.

Burning previously ungrazed plots resulted in large increases in the frequencies of 2 weedy taxa, prostrate spurge and foxtail, probably as a result of an increase in light after the removal of a deep litter layer. It also resulted in small increases in the frequency of the native forbs, leadplant and ground cherry, and a small decrease in the frequency of smooth brome grass. Contrary to expectation, fire did not measurably increase the relative basal cover of native grasses or decrease the cover of introduced grasses. The most dramatic effect of fire was its effect on woody taxa. A high proportion of the stems of 11 shrub species were killed (mean = 70%). However, fire did not eliminate these woody taxa because most species responded by vigorously resprouting. Nonetheless, while fire does not remove shrubs from the prairie, it can improve pasture by making species such as western snowberry (*Symphoriocarpos*) much more palatable to cattle as tender young sprouts rather than tough, woody stems.

The results of this manipulative experiment reveal that long-term management of the paddocks is responsible for the clearest trends seen. Long-term grazed paddocks had higher frequencies of weedy species, rosette-forming species and grasses, such as *Bouteloua*, that are known to respond positively to grazing. They also maintained a greater diversity of forbs than did ungrazed paddocks. Release from grazing caused few measurable changes; this may be because this prairie has maintained a relatively high quality under the rapid-rotation grazing system employed there.

Other published research indicates that both grazing and fire, and ideally a combination of both, can be used to maintain the diversity of prairie plant communities. It also shows that complete neglect or excessive grazing will lead to the long-term erosion of the quality of prairie vegetation. This study, though not documenting dramatic effects of different grazing systems or spring fire, concurs with those conclusions. A more detailed description of results can be found in the research report entitled, "Response of tallgrass prairie vegetation to rotational versus season-long grazing systems and spring fire," included in Research Addendum.

In retrospect, we would have allowed more lead time to secure permission to experimentally graze paddocks which had been enrolled in the CRP. Otherwise procedures were implemented largely according to plan.

The substantial balance remaining in this budget is partially due to the savings in publication costs for the booklet, *Landowner's Guide To Prairie Management In Minnesota* because of production details being done in conjunction with University Relations staff at the University of Minnesota, Crookston. Had this work been done by a private vendor, it would have been considerably more expensive.

LCMR BUDGET: 52,563
BALANCE: 11,106

Result 2. Livestock production using prairie species (Greg Cuomo, Leader).

Warm-season native grasses once dominated the landscape of western Minnesota. In recent times they have been replaced with annual grain crops and cool-season grass pastures. Native grasses can play an important role in livestock operations in this region. In addition, native warm-season grasses provide habitat and food for wildlife, have aesthetic value, conserve soil by reducing erosion, serve as water filters to help ensure a clean water supply, and can economically and efficiently recycle human and livestock waste as fertilizer in an environmentally friendly manner.

The goal of this research was to identify effective grazing management strategies for warm-season grass pastures in the North Central Region. Previous research and experience suggested that neither continuous grazing nor a complete absence of grazing is conducive to the persistence of warm-season, native tallgrass plant communities. However, it is not well understood what grazing management strategies will lead to the persistence of desirable plant communities. In addition, different grazing management strategies may favor some native grass plants over others. Specific objectives of this research were to evaluate effects of grazing management on species composition, persistence, and productivity of native warm-season grass plant communities.

A grazing experiment evaluated effects of high and low stocking rates and continuous and rotational grazing systems. Yearling dairy heifers grazed warm-season grasses at high and low stocking rates under continuous grazing or in 2, 4, 8, 16, or 32-paddock grazing systems. Native grasses were established in 1997 and included big bluestem, Indian grass, switchgrass, sideoats grama, and little bluestem. These pastures were grazed for 48 days from late-June through mid-August in 1999 and 2000.

At the initiation of the study, big bluestem, Indian grass, and sideoats grams dominated the native grass pastures used in this trial. During the 2 years of this study, animal performance data were collected. Average daily gain over the 2 years averaged 1.41 lb/d. This is below the goal of 2 lb/d set by many livestock producers. However, 1.41 lb/d is greater than the daily gain of animals grazing cool-season pastures at the West Central Research and Outreach Center at Morris during the same mid-summer time period. Average daily gains were similar among grazing treatments averaging 1.41, 1.42, 1.45, and 1.38 lb/d for high and low stocking rates and for continuous and rotational grazing over the 2 grazing seasons, respectively. If animal performance is similar across grazing systems, as suggested by these data, then grazing system impact on plant communities and wildlife habitat could be used as the determining factor when selecting a grazing system for warm-season native grasses.

Change in species composition was not detected in this study. Factors which may account for this include, short duration (2 years) of the study, 2) animals were removed from the trial in mid-August allowing plants to have a lengthy period to mediate negative effects of grazing and restore energy reserves before frost, and 3) a fairly heavy infestation of quackgrass which may have impacted community dynamics.

Previous research and experience indicated that grazing management does affect native grass plant communities. In this study, stands were managed as per conventional recommendations (grazed in mid-summer, with a late-season rest). Perhaps if grazing would have been continued later in the season, an impact of grazing management on native grass plant communities would have been evident. Also, it has been shown that native grass plant communities may be fairly stable over long periods of time, even under some mismanagement. The 2 years in which this study was conducted may not have been enough to detect impacts of grazing management on these plant communities.

The similar animal performance and short-term plant community stability demonstrated in this study suggests that when a late-summer rest period is provided before frost, management for wildlife habitat could be used as the determining factor when identifying a grazing system for native grass pastures. The native grass mixture used in this study was relatively simple, and did not include forbs. The persistence of desirable, but minor, species could also be a criterion used for selecting grazing systems in native grass pastures.

LCMR BUDGET: 52,563
BALANCE: 534

Result 3. Fire and grazing effects on breeding prairie birds (Daniel Svedarsky, Leader).

Burning effects on birds

We evaluated effects of post-burn age (year of burn, 1 year post-burn, and 3+ years post-burn) on breeding grassland birds in dry, moist, wet, and brush prairie habitats. A total of 27 plots, 3.5-16 hectares in size, were distributed throughout the study area. Breeding bird richness and density were determined by the Stewart and Kantrud strip transect census. Surveys were conducted twice on each plot from late-May through June during peak singing periods, between sunrise and 1000 hr. Vegetation measurements were taken from mid-June through mid-July to determine how bird density and species richness may be related to vegetation variables. Twenty to 40 systematically located Robel pole and Daubenmire plot readings were taken to estimate vegetation height, percent cover by growth form (graminoid, forb, woody), visual obstruction reading, and litter depth. Post-burn ages of study sites were determined from prescribed burning/wildfire records from the Department of Natural Resources, The Nature Conservancy, and private landowners.

We recorded 45 species of birds on plots in 2000 and 41 in 1999. The 4 most common species were savannah sparrow, LeConte's sparrow, bobolink, and clay-colored sparrow. Savannah sparrows and LeConte's sparrows occurred in relatively high densities on each of the habitat types. LeConte's sparrows, however, appeared to strongly select against Year-0 burn-age plots during both 1999 and 2000. Le Conte's and Clay-colored Sparrows appeared to strongly select against Year-0 burn-age plots. Clay-colored Sparrows preferred brush prairie to other prairie types. While Bobolinks selected against brush prairie plots in both years of the study, they showed mixed results in their selection for burn age. To improve conditions for more grassland bird species, grassland units should be rotationally burned and in a mosaic pattern so that a variety of post-burn age grassland units are available within a management area. These data will be part of a Master's thesis at the University of North Dakota and will be disseminated to agency and private prairie managers.

Grazing effects on birds

Sampling procedures and design were similar in evaluating grazing effects as the burn effects study. The highest number of individuals on any plot was 26 on a moderately-grazed, dry prairie. Species richness was highest (10) on a moderately-grazed brush plot, while 2 other plots (moderately-grazed, mesic and heavily-grazed dry) tied for the lowest with 2 species. Savannah sparrows were the most abundant bird species (~37% of total) and occurred in all prairie types. Grasshopper sparrows were the second most abundant and were found on dry and brush prairie types, a small portion on mesic prairies, and none on wet prairie plots. Clay-colored sparrows, western meadowlarks, and bobolinks were similar in abundance. Clay-colored sparrows were found primarily on brush plots but on other plots if there was brush present. They had a high frequency of occurrence on lightly-grazed pastures (~92%). Western meadowlarks were never very abundant on any site, but were present at least once on every prairie type and grazing intensity category. Bobolinks occurred mostly on wet, brush, and mesic prairie under light to moderate grazing, and were always observed perching at a height of 3 feet or so from the ground. Le Conte's sparrows were the 7th most abundant and were present in all prairie types, but none were observed in heavily-grazed pastures. Sedge wrens were generally quite abundant throughout the study area on wetter prairies.

Effects of rapid rotation grazing on nesting grassland birds were evaluated on the 645-acre Dean Elmer Farm near Evansville, MN. A Savory-cell grazing system is in operation there with triangular-shaped grazing paddocks radiating outward from a centrally positioned water source. Cattle graze a paddock for 2-3 days and are then moved to another paddock, allowing a 20-30 day rest period between grazing sessions. A stocking density of about 1.7 animal units/acre was applied using mostly Simmental cow/calf pairs. The terrain is quite rolling on gravelly substrate and is composed of largely native vegetation typical of dry prairies except for interspersed flatter areas that were once cultivated and have since reverted to mostly bluestem grasses, smooth brome and quackgrass. Two paddocks were ungrazed for 12+ years and served as locations for control plots. Sixty-two nests were found by systematically searching 14, 2.47-acre (1-hectare) plots and monitored every 3 days through fledging, abandonment, or depredation. Clay-colored sparrows, vesper sparrows, and grasshopper sparrows comprised 92% of all nests monitored. Mayfield nest success for these 3 species was 0.93 (n=51) in grazed plots, and 0.94 (n=11) in ungrazed plots (p>.05). There were no apparent differences in nesting success between grazed and ungrazed plots in this study area in 2001.

In hindsight, more lead time for data analysis should have been planned. Project leader Svedarsky was ill during May and June and this unexpected emergency caused a backlog in bird data analysis which is on-going (See Research Addendum). The budget for bird research was mostly expended.

LCMR BUDGET: 52,566
BALANCE: 37

Result 4. Publication of bulletin, LANDOWNER'S GUIDE TO MANAGEMENT OF PRAIRIE IN MINNESOTA (formerly proposed as FIRE AND GRAZING MANAGEMENT OF PRAIRIE IN MINNESOTA.

In press. Three copies of prepublication proofs are enclosed and publication of 3500 copies is scheduled for completion by 15 August.

There was not a separate account established for this result. Publication funds came from budgets managed by Svedarsky (Northwest Research and Outreach Center, U of MN, Crookston) and Kuchenreuther (U of MN, Morris).

Subproject One – FELTON PRAIRIE STEWARDSHIP PLAN FOR PUBLIC LANDS

V. DISSEMINATION:

Results of *subproject one* (Aggregate Resource Evaluation Report: Rotosonic drilling and Stewardship Plan) were disseminated to members of the aggregate industry, conservation groups, members of the broad group of stakeholders involved in the Clay County Beach Ridges Forum, and other citizen groups. The Stewardship Plan will also be posted to the Clay County web site (http://www.co.clay.mn.us/AboutUs/CurEvent.html) and the Red River Basin Information Network website maintained by D.N.R. Prairie Biologist Peter Buesseler.

Workshops:

Felton Prairie will be the official site to host **Minnesota Prairie Day 2002** on 10 August 2002 (<http://www.dnr.state.mn.us/snas/prairieday/index.html>). This project will be profiled at this event (See enclosed program). Prairie Day is an annual event sponsored by MN DNR, conservation groups, and local government jurisdictions.

Paper presentations:

Krohn, A. *How a landscape architect views ecosystem restoration*. Annual meeting of The Wildlife Society. Bismarck, ND. 22-27 September 2002. (Presentation at national meeting which will profile the Clay County Stewardship Plan and its development.)

Magnusson, T. The results from this project will also be used as part of a presentation at the statewide Aggregate Materials Conference in St. Cloud. 6-7 March 2003.

VI. CONTEXT:

a. **Significance:** This project is significant for the following reasons:

- it built on the work of the Clay County Beach Ridges Forum
- it used the knowledge and expertise of local partners
- it is a large scale demonstration of sustainable development with public agencies in a leadership role
- it served as a positive example for the entire Red River Valley and significantly added to the base of knowledge
- the Felton Prairie Complex has statewide significance
- timeliness - rebuilding after the flood of 1997 as well as construction of future flood control projects in the Red River Valley will add to the increasing demand for aggregate materials

b. **Time:** This project did not exceed 3 years.

c. **Budget Context:**

1. **LCMR Budget History:**

- 1995 to 1997, Clay County Beach Ridges Forum funded at $85,000

2. **Non-LCMR Budget History:**

- 1994, Minerals Team of the Sustainable Development Initiative toured Clay County and referenced Felton Prairie in their report.
- 1995, cooperative project to restore 2 gravel pits to prairie in Buffalo River State Park. Funding came from Minerals Environmental Cooperative Research at DNR and the Aggregate Material Tax in Clay County. Other contributors were The Nature Conservancy and Kost Brothers, Inc. (aka CAMAS, Inc.) Estimated project cost was $60,000.
- 1995 - 1997, DNR completed map coverages in Clay County including Public Land Survey data layer, aggregate resources, and County Biological Survey information.
- 1997, ad hoc committee established to act on recommendations from the Clay County Beach Ridges Forum. Ad hoc committee now known as the **Felton Prairie Stewardship Committee**.
- 1997, under leadership of ad hoc committee, cooperative drilling program conducted by MnDOT and DNR on selected public lands in the Felton Prairie Complex at an estimated cost of $7,500.

Minnesota Prairie Day
Felton Prairie, August 10, 2002

The event 'headquarters' will be located 2 miles south of the town on Felton on US Hwy 9. Then go 3 miles east on County Road 108 to the end of the road. Signs will direct visitors to a tent and display area. We'll also have refreshments for Prairie Day visitors at the tent.

10:00 - Welcome and Recognition Ceremony

- We will be acknowledging over a half-century of prairie stewardship at Felton and inviting many of the past landowners and groups who have played a role here. We will also be recognizing Clay County Board's adoption of the new *Felton Stewardship Plan.*
- The Nature Conservancy will be presenting it's *2002 Government Relations Award* to Senator Keith Langseth, from Glyndon

11:00 - 12:00 Prairie Activities Concurrent 45-minute field presentations on:

- **Prairie Plants** – Dr. Richard Pemble will lead a walk focusing on prairie plants and their uses by Native Americans
- **Pyro-botany** – TNC will demonstrate prescribed burning and discuss other aspects of managing prairies to keep them healthy
- **Prairie Birds** – Felton Prairie is a nationally recognized destination for 'birders'. The Fargo/Moorhead Chapter of the Audubon Society will lead this hike.
- **"Roaming the Prairie"** – Joe Gartner, Red River Interpretive Services, will lead a family & kid oriented exploration of the prairie.

12:00 – 1:00 Lunch (box lunches available for purchase, free refreshments)

- Prairie History – Stories of our prairie past. Mark Peihl, Clay County Historical Society

1:00 – 2:00 Prairie Activities Concurrent 45-minute field presentations on:

- **Prairie Insects** – Dr. David Rider has a long-term research project going on at Felton. He will show participants his active traps, what we are collecting, and explain why this research is important.
- **Going underground: A visit to a gravel pit** – Gravel industry representatives will take us into the Clay County gravel pit to explain the geology of the area and show 'how gravel is made'
- **Prairie Reconstruction** – The US FWS will explain the prairie reconstruction project underway at Felton, discuss techniques and equipment for planting prairie grasses and flowers.
- **"Roaming the Prairie"** – Joe Gartner, Red River Interpretive Services, will lead a family & kid oriented exploration of the prairie.

- 1998, same committee initiated a cooperative project to reclaim a 77-acre gravel pit to prairie. Estimated cost is $100,000 with funding from the county gravel tax and DNR, and in-kind support from aggregate industry and The Nature Conservancy.

3. **Budget summary for the subproject period:**

Personnel	**$ 50,000**
Equipment	**$ 3,000**
Acquisition	**$ 0**
Development	**$ 30,000**
Other	**$ 109,308**
TOTAL	**$ 192,308**

VII. COOPERATION: Members of the Felton Prairie Stewardship Committee included:

Clay County: Jon Evert, Jack Cousins, **TIM MAGNUSSON** (Subproject coordinator)
Department of Natural Resources: Walt Johnson, Martin Wiley, Doug Hedtke, Peter Buesseler, Cindy Buttleman
U. S. Fish and Wildlife Service: Doug Wells
Department of Transportation: Paul Munsterteiger
Aggregate Industry: Leroy Turner, Dan Ames, Bruce Squires, Mike Rose, Bob Bieraugel, Norman Jagger,
The Nature Conservancy - Brian Winter
University of Minnesota – Daniel Svedarsky
Minnesota State University, Moorhead – Richard Pemble

VIII. LOCATION:

The project area is the Felton Prairie Complex in Clay County, 4 miles east of Felton on the Glacial Lake Agassiz beach ridge. Due to the natural heritage significance and the economic importance of Felton Prairie, this work will have an impact throughout the Red River Valley and the state.

Subproject Two - EFFECTS OF FIRE AND GRAZING ON PRAIRIE VEGETATION, LIVESTOCK PRODUCTION AND BIRDS IN WESTERN MINNESOTA

V. DISSEMINATION:

Information gained from these results has been and will be disseminated to livestock producers, conservation personnel (U.S. Fish and Wildlife Service, Natural Resource Conservation Service, and the Minnesota Department of

Natural Resources, The Nature Conservancy), U of MN Extension personnel, and interested citizen groups through a variety of field days, popular and technical publications, and meetings/conferences.

Publications:

Svedarsky, W.D., M.A. Kuchenreuther, G.J. Cuomo, P. Buesseler, H. Moechnig, and A. Singh. 2002. *A landowner's guide to prairie management in Minnesota*. Northwest Research and Outreach Center, University of Minnesota, Crookston, MN 36 p. **In press**. To be initially distributed at the Minnesota Prairie Day celebration on 10 August 2002 at the Felton Prairie in Clay County (http://www.dnr.state.mn.us/snas/prairieday/index.html) and thereafter widely distributed via agency and University contacts. A pdf copy will be posted on the web site of the Northern Prairie Wildlife Research Center, U.S.G.S., Jamestown, ND - http://www.npsc.nbs.gov/, and also on the MN DNR web site at **http://www.dnr.state.mn.us/ecological_services/prairies.html**.

Svedarsky, W. D., J. E. Toepfer, R. L. Westemeier, and R. J. Robel. 2002. *Effects of management practices on grassland birds: greater prairie-chicken.* Northern Prairie Wildlife Research Center, U.S.G.S., Jamestown, ND. 37 p. Partial support. **In press**.

Driscoll, M.A, J. P. Loegering, V. B. Cardwell, and W. D. Svedarsky. *Grassland bird reproductive success on rotationally grazed CRP prairie in western Minnesota.* Manuscript in preparation for submission to The Loon.

Engelstad, J.L. *Effects of postburn age and prairie type on breeding birds in northwest Minnesota*. Master's thesis in preparation. University of North Dakota, Grand Forks..

Svedarsky, W.D., R. Sayre, and J. L. Engelstad. 2001. *The Mentor Prairie Wildlife Management Area: Assessment and management considerations.* A management plan for a DNR wildlife management area. Northwest Research and Outreach Center, University of Minnesota, Crookston. 70 pages plus Appendix. Partial support.

Reports: (Also see Research Addendum)

Cuomo, G. J. and A. Singh. *Livestock performance and plant persistence when grazing warm-season native grasses.*

Driscoll, M.A, J. P. Loegering, V. B. Cardwell, and W. D. Svedarsky. *Grassland bird reproductive success on rotationally grazed CRP prairie in western Minnesota.*

Engelstad, J. L., W. D. Svedarsky, and R. D. Crawford. *Effects of pos-tburn age and prairie type on breeding birds in northwest Minnesota.*

Kuchenreuther, M. A. *Response of tallgrass prairie vegetation to rotational versus season-long grazing systems and spring fire.*

Weltikol, M.L. and W. D. Svedarsky. *Effects of grazing intensity and prairie type on breeding birds in northwest Minnesota.*

Workshops:

Prescribed prairie burning: the principles and practice. A professional training workshop for resource specialists of the Natural Resources Conservation Service. 7-9 May 2001. Presented at University of Minnesota, Crookston. Partial support.

Paper presentations:

Driscoll, M.A, J. P. Loegering, and V. B. Cardwell. *Grassland bird reproductive success on rotationally grazed CRP prairie in western Minnesota*. Midwest Fish and Wildlife Conference, Des Moines, IA. 9-12 December 2001.

Engelstad, J. L., W. D. Svedarsky, and R. D. Crawford. *Effects of post-burn age and prairie type on breeding birds in northwest Minnesota*. Midwest Fish and Wildlife Conference, Des Moines, IA. 9-12 December 2001.

Svedarsky, W. D. *The greater prairie chicken*. Presentation at 3rd annual Sully's Hill Birding and Nature Festival. Devil's Lake, ND. 1-4 August 2002.

Cuomo, G. 2001. *Pasture management*. Minnesota Dairy Forage Conference. St. Cloud, MN 2001.

Other presentations:

Kuchenreuther: Meeting of CURE (Clean Up the River Environment), public programs at Big Stone National Wildlife Refuge, and meetings of local farmers interested in sustainable agriculture, as well as through courses taught at the University of Minnesota, Morris (e.g., Ecology, a course for Biology majors; and Conservation Biology, a general education course for non-majors).

Svedarsky: Annual conference of the Minnesota Prairie Chicken Society, discussion meeting regarding the Prairie Passage initiative, and classes at the University of Minnesota, Crookston (Land Use Planning, Integrated Resource Management, and Wildlife Habitat Management Techniques).

Cuomo: At the West Central Research and Outreach Center there was a series of 6 "pasture walks" in 2001 where changing forage management throughout the year was discussed and growers were exposed to the integration of native grasses into grazing management systems. Also participated in 6 pasture walks on producer farms in western Minnesota.

VI. CONTEXT:

a. Significance: This project was significant for the following reasons:

- Management effects of burning and grazing on prairie vegetation and birds in the Northern Tallgrass Prairie are poorly understood and this subproject made a contribution toward that information base.

- The largest proportion (75%) of remaining native prairie in Minnesota is privately owned and much is in need of better management to enhance plant diversity, wildlife habitat, and livestock production. The landowner guide will help fill that information void.
- This subproject is helping to synthesize existing published and unpublished information on prairie management in western Minnesota to make it available to user groups for application and to serve as a base to add further research findings to.
- The information developed in this subproject will complement that developed in other studies underway in northwest Minnesota; particularly a U.S.G.S. effort investigating prairie birds vs. habitat size and landscape matrix relationships and another evaluating management effects on prairie insects.

b. **Time:** Outreach activity and data collection in this subproject took place over the time span of 3 years.

c. **Budget Context:** This subproject had some relationship with past work funded by LCMR and NON-LCMR projects. Following is a summary of those projects with respective funding levels, and a detailed budget for this subproject:

1. **LCMR**. Similar to, MINNESOTA FOREST BIRD DIVERSITY INITIATIVE = $750,000. Extension of, SUSTAINABLE GRASSLAND CONSERVATION AND UTILIZATION = $125,000 and PRAIRIE-GRASSLAND LANDSCAPES = $125,000. Will use partial results of, COUNTY BIOLOGICAL SURVEY = $2,100,000.

2. **NON-LCMR.** Development of management plan for the Mentor Prairie Wildlife Management Area (Source = North Am. Waterfowl Conservation Act) = $30,000. A grant to Daniel Svedarsky concluded August, 1997. Although not a specified match requirement for this subproject funding, all 3 cooperating University units (Northwest Research and Outreach Center (ROC), West Central Research and Outreach Center, and U of Minnesota, Morris) contributed salary time, phone, and other support during the project and in-kind support in the use of equipment. The Northwest ROC provided a total value of $10,000 over the 3-year funding cycle; the West Central ROC, a total of $77,300; and the University of Minnesota, Morris, ~ $10,000 from in-kind and other support. In addition, a sum of $8,000 was available through a grant awarded to Margaret Kuchenreuther, U of Minnesota, Morris. These funds were a cooperative agreement with the U.S. Fish and Wildlife Service (USFWS), with the purpose of implementing a monitoring system to compare effects of rotational and year-long grazing on native prairie vegetation and grassland bird communities. The period covered by this agreement extended until 30 September 1999. Because of the similarity of that project to this one funded by LCMR, the same sites were used for each, the same sampling methods were employed,

and some of the same personnel worked on both projects. Funds from the USFWS project were used to establish and sample permanent plots prior to the beginning of LCMR funding (thus reducing start-up costs the first year of this project). LCMR funds were used to continue monitoring of sites beyond September 1999 when funding from the USFWS ended. In this way, longer term monitoring enhanced both projects.

3. **The budget summary for the subproject is as follows:**

Item	Percent effort	Cost
Personnel:		
Overall project manager & bird research leader, **Daniel Svedarsky**	10%	8,300
Graduate student (birds)	43%	24,080
Undergraduate student (birds)	25%	7,680
Vegetation research leader, **Margaret Kuchenreuther**	25%	26,000
Undergraduate assistants (2) (vegetation)	20%	11,900
Livestock research leader, **Greg Cuomo**		0
Assistant scientist (livestock)	40%	29,800
Summer assistant (livestock)	25%	6,000
Equipment (prescribed burning hand tools, marking stakes, electric fencing supplies)		1,500
Acquisition		0
Development		0
Other		
Printing / advertising		15,000
Total travel		16,250
Vehicle and equipment lease (pickup, tractor and gyromower for firebreak installation, ATV)		2,800
Office supplies		1,272
Miscellaneous supplies / maintenance		5,730
Communications		750
Data analysis		630
	TOTAL	**$157,692**

VII. COOPERATION:

This subproject had a number of cooperators who providing input to subproject development and implementation, including private landowners who allowed data collection on their property. Principal cooperators included:

Peter Buesseler, Prairie Biologist
Minnesota Department of Natural Resources
Fergus Falls, MN

Dean Elmer, Livestock Producer
Evansville, MN

Doug Johnson, Biometrician/Ornithologist
Northern Prairie Wildlife Research Center
Jamestown, ND

Brian Winter, Stewardship Director
The Nature Conservancy
Glyndon, MN

Terry Wolfe, Wildlife Manager
Minnesota Department of Natural Resources
Crookston, MN

VIII. LOCATION:

Field work for this subproject was carried out in a tier of counties from Stevens County in the south and north to Polk County. Study sites included the West Central Research and Outreach Center at Morris, Dean Elmer farm in Douglas County, 3 privately-owned native pastures in Pope County, the Felton Prairie Complex in Clay County, and the Mentor Prairie Wildlife Management Area in Polk County.

1999 Project Abstract

For the Period Ending June 30, 2001

TITLE: Integrated Prairie Management
PROJECT MANAGER: W. Daniel Svedarsky
ORGANIZATION: Northwest Research and Outreach Center (formerly Northwest Experiment Station, University of Minnesota.
ADDRESS: Crookston, MN 56716
WEB SITE ADDRESS: (If applicable)
FUND: Minnesota Environment and Natural Resources Trust Fund
LEGAL CITATION: ML 1999, Chap. 231, Sec. 16, Subd. 7d
(Agriculture and Natural Resource Based Industries) INTEGRATED RESOURCE MANAGEMENT.

APPROPRIATION AMOUNT: $ 350,000

This project was made up of 2 subprojects. The first examined challenges of conserving prairie in the Felton Prairie Complex of Clay County where it overlies valuable aggregate resources. This included, 1) an aggregate inventory using rotosonic drilling, 2) the reclamation of an abandoned gravel pit to a wetland and prairie reconstruction to provide a place for public interpretation of the Felton Prairie Complex and adjacent gravel mining activities, and 3) integrated stewardship planning. A site-specific stewardship plan was developed for about 2,000 acres of public land within the Complex with emphasis on developing a conflict resolution process for the 800 acres containing both prairie and gravel. The process recognized society's interest in prairie conservation as well as the need for aggregate resources. The second part of the project researched management effects of fire and grazing on prairie vegetation and grassland birds, and the use of prairie vegetation by livestock at selected sites in a 9-10 county area, including Clay County. Rotational grazing contributed to the maintenance of desirable prairie plants more than continuous grazing or no grazing. In spite of a short study period, prescribed burning increased desirable prairie plants over no-burn controls. The post-burn age of prairie plots affected birds differently depending on their habitat requirements, emphasizing the need for a mosaic of post-burn ages of prairie management units in the landscape. Prairie vegetation can provide desirable livestock forage during the warm part of the grazing season since many native grasses grow best then. Moderately-grazed prairie contained more birds that either heavily grazed or lightly-grazed plots. A landowner's guide to prairie management was prepared and will be widely distributed to individuals and agency prairie managers. It contains finding of this study and other research which is applicable to native prairie management and planting prairie in aggregate-mined areas.

TABLE OF CONTENTS – RESEARCH ADDENDUM

ORIGINAL SUBMISSION

B-7. **RESEARCH SUBPROJECT:**

Addendum - Description of Research Subproject Two for Peer Review

Title: EFFECTS OF FIRE AND GRAZING ON PRAIRIE VEGETATION, LIVESTOCK PRODUCTION, AND BIRDS IN WESTERN MINNESOTA

I. ABSTRACT:

The research component of this subproject consists of 3 parts; fire and grazing effects on prairie vegetation, livestock production using prairie species (principally warm-season grasses), and fire and grazing effects on breeding prairie birds. Each part will be coordinated by a separate investigator but with close collaboration to ensure a system perspective and comparable methodology. The investigators will meet at least once monthly to coordinate efforts. The study area is located in western Minnesota from Stevens and Pope counties, north to Polk County, a distance of some 90 km. Representative study sites of remnant prairies will be located within this area that are managed according to various burning and grazing regimes. Effects of these management practices will be evaluated with the goal of providing guidelines that can promote better sustainable management of prairies for the conservation of vegetation and birds as well as livestock production. Results will be combined in a bulletin entitled, **Fire and Grazing Management of Prairie in Minnesota**.

PART ONE: PRAIRIE VEGETATION

II. BACKGROUND:

Prairie in the Midwest has been reduced to less than 1% of its former occurrence. Therefore, the question of how best to manage the remaining prairie tracts to maintain their diversity, prevent invasion of exotic species and woody vegetation, and promote their use by native wildlife, is an important one. Additionally, though federal, state and non-governmental organizations (e.g., The Nature Conservancy) have been actively involved in acquiring remaining tracts of prairie, many acres remain in private ownership. Therefore, a second important question is whether native prairie can be used to provide an economic benefit to its owners (e.g. through use as pasture for livestock) without radically changing its species composition, or eroding its ability to support wildlife.

Along with climate, fire and grazing by large ungulates were historically important factors influencing the development and maintenance of prairie plant communities

(Axelrod 1985). Yet there is much debate about the appropriate way to apply each as a management tool in prairies (A vast literature exists in each area. Among others, see reviews by Collins and Wallace 1990 [effects of fire] and by Painter and Belsky 1993, Dyer *et al.* 1993 and McNaughton 1993 [effects of grazing].)

Fire removes litter allowing better light penetration and restoring some nutrients. It inhibits the growth of woody vegetation, while stimulating the growth of prairie grasses and forbs. Early spring burns enhance growth, vegetative reproduction and flowering of warm-season native grasses, and help control non-native, cool season grasses (Hulbert 1988, Collins and Wallace 1990). Thus, prescribed burns are currently the most important tool used in the restoration and management of remnant prairies.

Unlike a single episode of fire, grazing removes standing crop and litter, often repeatedly, throughout the growing season (depending upon the grazing system and length and frequency of pasture rest periods). Grazers also remove biomass much more selectively than fire does, and grazers tend to produce a patchier form of disturbance than fire through localized trampling of vegetation, mechanical disturbance of the soil, and deposition of urine and feces (Milchunas *et al.* 1988, Huntly 1991). In addition, overgrazing has long been known to reduce the vigor of native plant communities, decrease the abundance of some native species and cause invasion by non-native grasses and weedy dicots (Weaver 1954).

It has also been noted that fire and grazing treatments can interact to alter the structure of vegetation beyond what either does alone. For example, bison have been observed to alter their pattern of grazing after fire (Coppock and Detling 1986, Vinton *et al.* 1993, Pfeiffer and Steuter 1994) and to graze little bluestem much more heavily after it has been burned (Pfeiffer and Hartnett 1995). Cattle also selectively graze burned areas (Don Kirby, personal commun.).

The aim of this research is to demonstrate how fire and grazing affect prairie plant communities in western Minnesota. This part of the subproject provides information to support the prairie bird research and livestock production parts. We will examine effects of fire and different grazing systems on prairie vegetation, including plant community composition, vegetation height, and litter accumulation. Using the information generated by the bird community work, we can determine how a particular management regime will affect birds through its effects on vegetation. Using data generated by the livestock production work, we can evaluate whether different management regimes can support profitable and sustainable livestock operations.

This portion of the research will address the following major questions:

1. Is there a significant difference in plant community composition and structure produced by fire in grazed and ungrazed stands of native prairie?

Specifically, we will look for significant effects of these treatments on:

a. the frequency and relative cover of warm-season, native grass *Decreasers*; such as big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachrium scoparius*), side-oats grama (*Bouteloua curtipendula*), blue grama (*Bouteloua gracilis*) and prairie dropseed (*Sporobolus heterolepsis*).

b. the frequency and relative cover of invasive, non-native, cool-season grasses such as Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*).

c. the frequency and relative cover of selected indicator species of native forbs, including reputed grazing *Increasers* such as; yarrow (*Achillea millefolium*), frost aster (*Aster ericoides*), sage (*Artemesia ludoviciana*) and stiff goldenrod (*Solidago rigida*)] and *Decreasers* such as; leadplant (*Amorpha canescens*), ground plum (*Astragalus crassicarpus*), and blazing star (*Liatris* spp.) (Weaver 1954).

d. the frequency and relative cover of invasive, non-native weed *Invaders;* such as, Canada thistle (*Cirsium canadensis*), leafy spurge (*Euphorbia esula*) and sweet clover (*Melilotus* spp.).

e. vegetation structure; height-density, depth of litter, and percent bare ground, variables which affect breeding bird communities (Paine *et al.* 1995).

2. How do the above vegetation attributes correlate with the bird communities as determined by the prairie bird research?

III. METHODS

Cooperators who have implemented different types of grazing systems on native prairie have been identified in Douglas, Polk, Clay and Pope Counties. Their grazing systems span the range from season-long grazing (Rutledge farm), to a 3-paddock rotation system (Frederickson farm), 4-paddock rotation system (Mentor Prairie), and an 11-paddock, short-duration (modified Savory cell system; see Savory 1988) grazing system (Elmer farm). Adjacent ungrazed stands of native prairie have also been identified as controls.

A detailed description of the sampling design for the Elmer Farm (Douglas County) follows and will be adapted as necessary to fit grazing systems employed on the other farm sites:

Two of the 11 paddocks have been in the Water Bank Program and have not been grazed for 10 years. The other 9 paddocks have been grazed, using a short duration system (where cattle are in a given paddock for 3 days before being moved to the next paddock), since 1981.

Two replicates of our experiment will include the following 4 combination of grazing and burning treatments:

<u>ungrazed paddock</u>
- unburned = CONTROL
- burned = UNGRAZED BURNED

<u>grazed paddock</u>
- unburned = GRAZED UNBURNED
- burned = GRAZED BURNED

In each paddock we will burn at least 2 areas of approximately 1000 m^2 each. We will choose 2 areas adjacent to the BURNED plots to be UNBURNED plots, matching the plots across all 4 treatments for soil type. This design will be replicated at least twice on the Elmer farm, utilizing both of the ungrazed paddocks and 2 grazed paddocks with comparable vegetation, soil, and topography.

During mid- to late summer of 1999 and 2000, each plot will be sampled in several ways. A standard 10-point frame will be used to estimate the relative cover of 5 vegetation classes: native grass, introduced grass, native forb, introduced forb, and bare ground. The frames will be randomly placed and 100 frames will be read per plot. Randomly placed 1/4 m^2 quadrat frames (at least 50 per plot) will be used to score presence or absence of indicator species, allowing an estimate of relative frequencies. Robel pole measurements will be taken at the same locations to estimate vegetation height-density. Litter depth will be measured at these points, as well.

We plan to implement this research approach (or a slight modification, as necessary) on the properties of at least 3 different cooperators who use different grazing systems. If possible, the same approach will be used in conducting a separate but closely related study (currently funded for federal FY 1998-99 by a U.S. Fish and Wildlife Service grant to Kuchenreuther), with the advantage of adding pastures of additional cooperators to our total sample. If time and resources allow, we plan to continue monitoring these additional sites, with funds provided through this LCMR grant, after the USFWS funding expires. Because of the similarity in goals for each of the studies, agreement has been reached with the USFWS to allow us to use funds from their grant to establish treatments for this study prior to the availability of LCMR funds in July 1999.

Using this on-farm research approach imposes several constraints on experimental design. One is the inability to replicate the design exactly across farms since each cooperator has his own way of managing his grazing system. Another is that the cooperator sets stocking rates, we do not. Also, we will be unable to gather baseline data from the sites before the grazing treatments begin, since the areas are already in use for livestock production. Additional unforeseen and uncontrollable complications could also arise during the course of the study because of the management concerns of a particular cooperator. For example, a prolonged and serious drought could induce a cooperator to make an unexpected change in his pasture rotation system to maximize the forage available to his cattle. We will not be able to control this. In spite of these limitations, the information gathered and the demonstration value of this work will be useful to promote better management of privately-owned prairie pastures.

Literature Cited:

Axelrod, D.I. 1985. Rise of the grassland biome, central North America. *Bot. Rev.* 51: 163-202.

Collins, S.L. and L.L. Wallace (eds.). 1990. *Fire in North American tallgrass prairies.* University of Oklahoma Press, Norman, OK.

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Hulbert, L.C. 1988. The causes of fire effects in tallgrass prairie. *Ecology* 69: 46-58.

Huntly, N. 1991. Herbivores and the dynamics of communities and ecosystems. Ann. *Rev. Ecol. Syst.* 22: 477-503.

McNaughton, S.J. 1993. Grasses and grazers, science and management. *Ecol. Appl.* 3: 17-20.

Milchunas, D.G., O. E. Sala and W.K. Lauenroth. 1988. A generalized model of the effects of grazing by large herbivores on grassland community structure. *Amer. Natur.* 132: 87-105.

Paine, L.K., G.A. Bartelt, D. J. Undersander and S.A. Temple. 1995. Agricultural practices for the birds. *The Passenger Pigeon* 57: 77-87.

Painter, E.L. and A. J. Belsky. 1993. Application of herbivore optimization theory to rangelands of the western United States. *Ecol. Appl.* 3: 2-9.

Pfeiffer, K.E. and D.C. Hartnett. 1995. Bison selectivity and grazing response of little bluestem in tallgrass prairie. *J. Range Mange.* 48: 26-31.

Pfeiffer, K.E. and A.A. Steuter. 1994. Preliminary response of Sandhills prairie to fire and bison grazing. *J. Range Manage.* 47: 395-397.

Savory, A. 1988. *Holistic Resource Management.* Island Press, Covelo, CA.

Vinton, M.A., D.C. Hartnett, E.J. Fink and J. M. Briggs. 1993. Interactive effects of fire, bison (*Bison bison*) grazing and plant community composition in tallgrass prairie. *Amer. Midl. Natur.* 129: 10-18.

Weaver, J.E. 1954. *North American Prairie*. Johnsen Publishing Co., Lincoln, NE.

IV. RESULTS AND PRODUCTS:

This study will enhance our understanding of short-term changes in plant community structure and composition produced by burning and grazing management. It will provide baseline data for continuing study of these effects. We will link these results to the information gathered about bird habitat preferences and livestock production, and formulate prairie management strategies that simultaneously benefit the prairie plant community, prairie bird communities, and livestock producers. The data collected in this project, combined with information gleaned from other studies, will result in the publication of a bulletin entitled, *Fire and Grazing Management of Prairie in Minnesota,* intended for use by conservation professionals and the lay public. It will also be disseminated to the general public by hosting field days, featuring tours of project sites and presentations by the cooperators. Finally, we plan to submit our results to peer-reviewed journals and present at appropriate professional meetings for broader dissemination to the scientific community.

V. TIMETABLE:

Spring 1999): Establish treatment areas. Do burn treatments. **(Before grant period begins; funded through grant from USFWS to Kuchenreuther)**

Summer - early Fall 1999: Conduct vegetation sampling. Analyze existing data set from previous burn experiment.

Winter 1999/2000: Analyze data, prepare interim report (due 1 Feb. 2000)

Summer - early Fall 2000: Conduct vegetation sampling

Winter 2000/2001: Analyze data, prepare materials for non-technical publications; prepare interim report (due 1 Feb. 2001)

Spring 2001: Repeat burn treatments (*contingent on grant renewal*)

Summer - early Fall 2001: Conduct vegetation sampling (*contingent on grant renewal*)

Winter 2001/2002: Analyze 3rd year's data (*if any*), prepare peer-reviewed

publications, prepare interim report (due 1 Feb. 2002)
Spring - early Summer 2002: prepare final report (due 30 June 2002)

VI. ITEMIZED BUDGET FOR PART 1, PRAIRIE VEGETATION

(See also Attachment B, Result 1)

CATEGORY	YEAR 1 1999-2000	YEAR 2 2000-2001	TOTAL
Faculty summer salary (+ fringe)	$ 6900	$19,100	$26,000
Undergraduate student employees - academic yr. (no fringe)	$ 1200	$ 1300	$ 2500
Undergraduate student employees- summer (+ fringe)	$ 2700	$ 6700	$ 9400
Mileage (@$.325)	$ 1000	$ 1500	$ 2500
Other travel expenses	$ 1200	$ 1500	$ 2700
Supplies	$ 1500	$ 400	$ 1900
TOTALS	$14,500	$30,500	$45,000

VII. RESUME OF MARGARET KUCHENREUTHER, PRINCIPAL INVESTIGATOR FOR PRAIRIE VEGETATION

CURRICULUM VITAE

Margaret A. Kuchenreuther, Ph.D.

Position: Associate Professor of Biology, University of Minnesota-Morris
Campus Address: Division of Science and Mathematics-Biology, 600 East 4th St., Morris, MN 56267
Campus Phone: (320)-589-6335

Education: Ph.D. Botany, University of Wisconsin-Madison, 1991,
M.S. Botany, University of Wisconsin-Milwaukee, 1986,
B.A. Biological Sciences, University of Northern Iowa, 1978

Professional Employment: Associate Professor of Biology, University of Minnesota, Morris, 1997 - present, Assistant Professor of Biology, University of Minnesota, Morris, 1991-97, Visiting Professor, Rocky Mountain Biological Laboratory, Summer 1997 and 1998

University of Minnesota - Morris Courses Taught: Biol 1003 Conservation Issues, Biol 1700 Biological Communications 1, Biol 1701 Biological Communications II, Biol 3700 Plant Systematics, Biol 3805 Plant Evolution, Biol 3850 Ecology, Biol 3940 Practicum in Biology, Biol 395x Directed Study, IS 1020 Inquiry: Values in a Changing World, IS 3853 Interdisciplinary Internship, Pol 3962H Senior Honors Project

Recent Publications:

Kuchenreuther, M.A. 1996. The natural history of *Aconitum noveboracense* Gray (northern monkshood), a federally threatened species. Journal of the Iowa Academy of Science 103(3-4): 57-62.

Kuchenreuther, M.A., C.T. Cole, J.A. Williams and K.C. Giese. 1996. Characterization of Black Hills *Aconitum* populations using genetic markers. Final report submitted to the Black Hills National Forest.

Reinartz, J.A., S. Horzen, K. Forbeck, J. Kline and M.A. Kuchenreuther. 1994. Development of vegetation over nine years in a planted field station prairie. University of Wisconsin-Milwaukee Field Station Bulletin 27(2): 1-17.

Smith, J.F. and M.A. Kuchenreuther. 1993. A floristic survey of Benedict Prairie (Kenosha County, Wisconsin). University of Wisconsin - Milwaukee Field Station Bulletin 26 (1): 10-24.

Kuchenreuther, M.A. 1991. Life history, demography and genetics of *Aconitum noveboracense*: implications for preservation and management of a threatened species. Ph.D. Thesis, University of Wisconsin-Madison.

Grants Received:

'The Effects of Rotational Versus Year-long Grazing on the Vegetation and Bird Communities of Native Prairie." U.S. Fish and Wildlife Service, 1998-99

"Characterization of Black Hills *Aconitum* Populations Using Genetic Markers." (co-authored with C.T. Cole) U.S. Forest Service, 1994-96

"Effects of Burn Regime on the Population Dynamics of Three Prairie Species." University of Minnesota Graduate School Grant-in-Aid of Research Program, 1994-95

Funding to attend the "Workshop in Plant Reproductive Biology" at Rocky Mountain Biological Laboratory. National Science Foundation, 1994

"Dissertation Research: Demographic and Genetic Consequences of Isolation in *Aconitum noveboracense*." National Science Foundation, 1989-90

Service and Outreach:

Vice-chair of UMM Campus Assembly, 97-99
Social Concerns Committee, University of Minnesota Senate, three year term, 98-01
Senator, University of Minnesota Senate, three year term, 95-98
Chair, Search committee of a tenure track Microbiologist/Biochemist, 97-98
Chair, Science IV Public Art Committee, 98-present
Science and Math Representative to the UMM Grants Advisory Committee, 97-present
Reviewed manuscripts for the *International Journal of Plant Science*, the National Biological Survey's *National Status and Trends*, and *The Natural Areas Journal*.
Conducted breeding bird surveys for the Minnesota Department of Natural Resources Niemackl Lakes project, Su96

Member of the U.S. Fish and Wildlife Service Endangered Species Recovery Team for Northern Monkshood, 1986-present

PART TWO: LIVESTOCK PRODUCTION

II. BACKGROUND

Warm-season native grasses once dominated the landscape of western Minnesota. Recently, they have largely been replaced with annual grain crops and cool-season grass pastures, but native grasses can play an important role in livestock operations in this region. Additionally, native warm-season grasses provide wildlife habitat, have aesthetic value, reduce soil erosion, serve as water filters to help ensure a clean water supply, and can economically and efficiently recycle human and livestock waste as fertilizer in an environmentally friendly manner. However, there is a paucity of research on the grazing ecology and management of warm-season grasses in the North Central region of the U.S., which is needed in order for livestock producers to appreciate the potential of native forage.

This research will have 2 components: one to be conducted at the West Central Experiment Station at Morris and the other to be conducted on-farm, described in the previous section on "Prairie Vegetation." The overall goal of this research is to identify effective management strategies for warm-season grass pastures in western Minnesota and disseminate this information to producers to aid in better understanding, and more effectively using, native pastures.

The research at the West Central Experiment Station will focus on effects of extensively vs. intensively managed grazing systems. Data gathered to date suggest that neither continuous grazing nor a complete absence of grazing is conducive to the persistence of warm-season native tallgrasses. However, it is not well understood which grazing strategies lead to the persistence of desirable plant communities and favor some native grasses over others.

Objectives of this research are to evaluate effects of grazing management on general botanical composition, persistence, and productivity of native warm-season grass plant communities. The hypothesis is that more intensive grazing and longer rest periods between grazing events will enhance the persistence of tallgrass prairie species, optimize livestock gain, and provide wildlife habitat values.

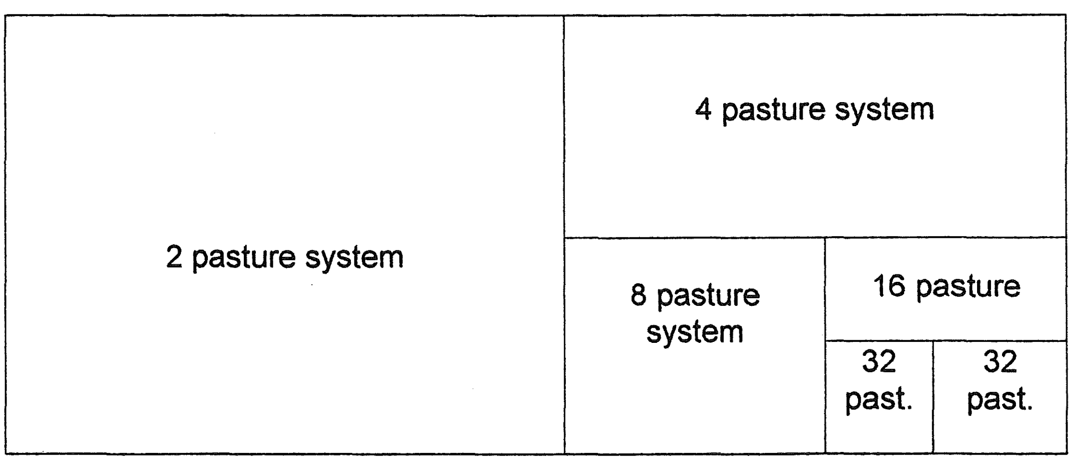
III. METHODS:

A mix of native warm-season grasses was established at the West Central Experiment Station at Morris on 12 ha in the spring of 1997. Grasses planted included species that would be expected to dominate at different stages of plant succession [**tallgrasses**: big bluestem (planted at 4.4 kg pure live seed(PLS)/ha), switchgrass (planted at 0.6 kg PLS/ha), and Indiangrass (planted at 3.3 kg PLS/ha); and **mid-grasses**: side-oats grama (planted at 1.1 kg PLS/ha) and little bluestem (planted at 0.6 kg PLS/ha)], and therefore may be more or less dominant under different grazing management systems. The area was grazed once in August 1998. Grazing treatments will be conducted from 1999 through 2000.

The experimental area was divided into 12, one-hectare paddocks. A unique experimental design will be used in this trial to evaluate many grazing strategies with a minimum number of animal groups (Figure 1). The trial will have 3 replications of 2 stocking rates and 6 grazing intensities. Stocking rate (animals/ha/yr) can have a great impact on a plant community's response to grazing.

Stocking rates used in this trial will be low (at Natural Resources Conservation Service recommendations) and high (25% greater than NRCS recommendations). The 6 grazing intensity treatments (animals/ha and length of each grazing event) will be continuous grazing and a simulated 2, 4, 8, 16, and 32-pasture system. Each replication and stocking rate will use 2 pasture units, one for continuous grazing and one for rotational grazing (Fig. 1). Therefore, each replication will be a block of 4 pasture units: continuous grazing at both high and low stocking rates and rotational grazing at both high and low stocking rates. Table 1 shows an example of the graze and rest periods in a theoretical 32-day rotation. Dairy heifers will be used to graze pastures. Prior to the beginning of grazing, heifers will be blocked by weight and age and randomly assigned to treatments.

Figure 1. Pasture layout for grazing intensity treatments for one stocking rate replication. An entire replication would be 2 of these units, one at a high and one at a low stocking rate.



1 pasture (continuous grazing)

Table 1. Days grazed and rested for each pasture management system in a 32-day pasture rotation.

Number of pastures	Days grazed	Days rested
1 (continuous grazing)	32	0
2	16	16
4	8	24
8	4	28
16	2	30
32	1	31

Plant cover and species composition will be estimated using a 10-point frame and collected prior to and after grazing each year. Forage production will be estimated by clipping 2, ¼ m^2 frames in each paddock prior to grazing. Forage production estimates on continuous grazed areas will be made with portable grazing exclosures and estimated monthly. Although precise estimates of animal weight gain for each grazing intensity treatment will not be available as a result of the study design, gross weight estimates from high versus low stocking rate and continuous verses rotational grazing will be estimated. Animals will be weighed every 2 weeks throughout the trial to assess weight change in the various systems. Robel pole estimates of vegetation height/density will be taken each fall for each treatment and used as an indicator of bird habitat. This research is being conducted at the West Central Experiment Station to provide experimental controls.

IV. RESULTS AND PRODUCTS:

Information derived from these studies will be disseminated in several ways. Field days will be conducted with presentations and reports from cooperators. This information will also be valuable for presentation at grazing conferences in Minnesota and the region. In addition, this research will lend itself to both non-technical and technical reports. This project will provide a sound basis for management of native pastures in this region.

V. TIMETABLE:

Pasture establishment	Completed, 1997
Fence construction	Completed, 1998
Grazing and other data collection	Summers 1999 and 2000
Progress reports	1 February 2000
	1 February 2001
	1 February 2002
Final report	30 June 2002

VI. ITEMIZED BUDGET FOR PART TWO – LIVESTOCK PRODUCTION:

(See also Attachment B, Result 2)

Category	Annual	2-year total
Assistant Scientist (40%)		
Salary and Fringe	14,900	29,800
Summer labor	3,000	6,000
Travel	2,400	4,800
Maintenance and supplies	1,915	3,830
Data/sample analysis	315	630
Total	**22,530**	**$ 45,060**

VII. RESUME OF GREG CUOMO, PRINCIPAL INVESTIGATOR FOR LIVESTOCK PRODUCTION

Gregory J. Cuomo
University of Minnesota/West Central Experiment Station
State Hwy 329
Morris, MN 56267

EDUCATION:

Texas A&M University	1981-84	Range Science	B.S.
Texas Tech University	1985-88	Range Science	M.S.
University of Nebraska	1989-92	Agronomy	Ph.D.

RESEARCH: I conduct research on pasture management and ecology. My pasture ecology research emphasizes grazing management strategies that enhance the persistence of desirable native grass plant communities and legumes in cool-season grass pastures. My pasture management research emphasizes the development of strategies that will allow producers to extend the current 150 day Minnesota grazing season to 210 days and to provide ample amounts of high quality forage during mid-summer.

OUTREACH: I have statewide outreach responsibilities for pasture and grazing issues. I have focus my outreach program on grazing management, pasture renovation and pasture fertility. As a consequence of working at an experiment station, I am also relied to present outreach topics and to serve as a reference for topics beyond pasture issues. Other topics include alfalfa management, Conservation Reserve program (CRP) planting and management, hay storage, and forage quality.

RECENT PUBLICATIONS: Refereed

1. Cuomo, G.J., B.E. Anderson, and L.J. Young. 1998. Harvest frequency and burning effects on the vigor of big bluestem, switchgrass, and indiangrass. J. of Range Manage. 51:32-36.

2. Cuomo, G.J., D.D. Redfearn, and D.C. Blouin. 1998. Plant density effects on tropical corn forage mass, morphology, and nutritive value. Agron. J. 90:93-96.

3. Cuomo, G.J., and D.C. Blouin. 1997. Annual ryegrass forage mass distribution as affected by sod suppression and seedbed preparation. J. Prod. Agric. 10:256-260.

4. Cuomo, G.J., D.C. Blouin, D.L. Corkern, J.E. McCoy, and R. Walz. 1996. Plant morphology and forage nutritive value of three bahiagrasses as affected by harvest frequency. Agronomy J. 88(1):85-89.

5. Cuomo, G.J., B.E. Anderson, L.J. Young, and W.W. Wilhelm. 1996. Harvest frequency and burning effects on monocultures of three warm-season grasses. J. Range Management 49(2):157-162.

6. Cuomo, G.J. and B.E. Anderson. 1996. Nitrogen fertilization and burning effects on rumen protein degradation and nutritive value of native grasses. Agronomy J. 88(3):439-442.

7. Cuomo, G.J., D.C. Blouin, and J.F. Beatty. 1996. Forage potential of dwarf napiergrass and a pearl millet by napiergrass hybrid. Agronomy J. 88(3):434-438.

8. Croughan, S.S., S.S. Quisenberry, and G.J. Cuomo. 1997. Bermudagrass somaclone resistance to fall armyworm (*Lepidoptera: Noctuidae*). J. Agric Entomology 14:73-79.

9. McCormick, M.E., G.J. Cuomo, and D.C. Blouin. 1998. Annual ryegrass stored as baleage, haylage, or hay for lactating dairy cows. J. Prod. Agric. 11:293-300.

10. Mooso, G.D., G.J. Cuomo, D.C. Blouin, and W.D. Pitman. 1996. Fertilizer effects on common bermudagrass on a Southwest Louisiana Coastal Plain Soil. J. Plant Nutr. 19:817-826.

11. Pitman, W.D., J.L. Hafley, G.J. Cuomo, and A.E. Kretschmer.1997. Stand regeneration of *Alysicarpus* and *Desmodium* germplasm in Louisiana. Crop Sci. 37:1373-1376.

OTHER PUBLICATIONS AND OUTREACH ACTIVITIES: Three refereed journal publications prior to 1996, 7 manuscripts in press or submitted to refereed journals, 1 book chapter in press, 19 proceedings papers, 24 abstracts, 10 Extension Bulletins/Fact sheets, 19 non-refereed research articles, 91 invited presentations, co-developed Univ. of MN grazing school.

PART THREE - PRAIRIE BIRDS

II. BACKGROUND:

Because of grassland habitat losses, prairie birds have shown steeper and more widespread declines than any other group of North American birds. Less than 1% of presettlement prairies remain in Minnesota. Many prairies are under public ownership (U.S. Fish and Wildlife Service, Minnesota Department of Natural Resources), and The Nature Conservancy – a private conservation organization, but substantial acreages are owned by private individuals who use them for grazing, haying or aesthetic enjoyment.

While the declining acreage of the prairie ecosystem is a critical problem, management of remaining prairies is equally important if grassland-dependent plants and animals are to be conserved and sustainable human uses provided for. Fire and grazing were natural occurrences on presettlement prairies and native plants and animals are adapted accordingly.

Birds in particular are commonly used as biological indicators of environmental conditions. But few studies (Tester and Marshall 1961, Johnson and Temple 1990, Svedarsky 1988) have evaluated effects of management practices, such as fire and grazing, on bird species in the Northern Tallgrass Prairie. Most studies have been conducted in more southerly portions of the tallgrass prairie; in Kansas (Zimmerman 1997), Missouri (Skinner 1975), and Illinois (Herkert 1994, Westemeier and Buhnerkempe 1982) where climate and species differences occur. Responses of prairie birds to fire in western Minnesota prairies could be similar to those noted by Johnson (1997) in mixed-grass prairie of central North Dakota but again, there are plant and bird species differences and greater amounts of precipitation in Minnesota result in taller and denser vegetation. Current studies in Wisconsin (Paine, et al. 1995) are evaluating grassland bird responses to rotational grazing of non-native forage species in intensive agricultural settings.

This study will expand on earlier findings in Minnesota and other areas by evaluating effects of post-fire age and grazing intensity on birds of dry, moist, wet, and brushy prairie habitats. This information will be useful to agency personnel and private landowners concerned with designing and managing landscapes and preserves for the conservation of prairie flora and fauna and/or using prairie vegetation for livestock forage.

Objective:

To evaluate effects of fire and grazing on the species richness, density, and community composition of prairie birds in dry, moist, wet, and brush prairie habitat types.

III. METHODS:

Study plots will be located from Stevens and Pope counties to the south and north to Polk County, a distance of approximately 90 km. Inventory data of the County Biological Survey and interviews with agency prairie managers will be used to identify representative plots of remnant prairie in northwest Minnesota.

With regard to grazing effects, 3 major questions will be addressed with a two-way factorial experimental design: (1) Does grazing intensity (as it affects vegetation structure) affect bird species richness, density, and community composition? (2) Does the prairie habitat type being grazed affect bird species richness, density, and community composition? and (3) Are there interactive effects between grazing intensity and habitat type?

The study plan is as follows:

	PRAIRIE HABITAT TYPE			
GRAZING INTENSITY	Dry	Moist	Wet	Brush Prairie
Light	3			
Moderate				
Heavy				
No-graze controls				

Three study plots, 10-20 ha in size, will be identified for each of the above cells and distributed throughout the study area to reduce latitudinal effects. Plots will be located in prairie tracts at least 32 ha in size to reduce edge effect. Dry, moist, and wet prairie study plots will have less than 10% brush cover (mostly aspen and willow) and brush prairie plots will have greater than 25% brush cover. Habitat type will be based on indicator plant species and soil types. Grazing intensity will be assigned as follows: heavy ($\geq$ 50% of annual growth removed), moderate (~ 25% removed), and light ($\leq$ 12.5% removed) but with subjective estimates of these removal rates following Kantrud and Kologiski (1982). No-graze control plots will be undisturbed (by grazing, mowing, or burning) for at least 3 growing seasons. Most of the grazing will be by cattle.

Breeding birds will censused by a strip transect method(Stewart and Kantrud 1972) conducted 2 times on each plot during the breeding season. The entirety of each plot will be censused. Vegetation will be measured once during the year of the bird census between mid and late June (approximate mid-point of breeding season) using 20 systematically located Robel pole and Daubenmire quadrat readings in each plot. Measurements will be made of vegetation height, percent cover by growth form (graminoid, forb, woody), height/density (Robel readings), and litter depth).

Similarly, for burning effects, a two-way factorial experimental design will evaluate the following questions: (1) Does post-burn age affect species richness, density, and community composition? (2) Does the habitat type being burned affect species richness, density, and community composition? and (3) Are there interactive effects between post-burn age and habitat type?

The study plan is as follows:

	PRAIRIE HABITAT TYPE			
POST-BURN AGE (YEARS)	Dry	Moist	Wet	Brush Prairie
0	3			
1				
3+				

The number of study plots sampled per cell and other protocol will be similar to the grazing study. For post-burn age categories; "0" will be located in prairies burned in late fall of the previous year or the spring of the census year, "1" will be prairies after 1 full growing season, and "3+", those with 3 or more growing seasons before sampling.

Literature Cited:

Herkert, J.R. 1994. Breeding bird communities of midwestern prairie fragments: the effect of prescribed burning and habitat area. Nat. Areas J. 14:128-135.

Johnson, D.H. 1997. Effects of fire on bird populations in mixed-grass prairie. Pages 181-206, in F.L. Knopf and F.B. Samson, eds. Ecology and conservation of Great Plains vertebrates. Springer, New York.

Johnson, R.G., and S.A. Temple. 1990. Nest predation and brood parasitism of tallgrass prairie birds. J Wildl. Manage:54:106-111.

Kantrud, H.A., and R.L. Kologiski. 1982. Effects of soils and grazing on breeding birds of uncultivated upland grasslands of the northern Great Plains. Wildlife Res. Rep. 15. U.S. F.W.S., Washington, D.C. 33 pp.

Paine, L.K., G.A. Bartelt, D.J. Undersander, and S.A. Temple. 1995. Agricultural practices for the birds. Passenger Pigeon 57:77-87.

Skinner, R.M. 1975. Grassland use patterns and prairie bird populations in Missouri. Pages 171-180 in M.K. Wali, ed. Prairie: A multiple view. Univ. of North Dakota Press, Grand Forks.

Svedarsky, W.D. 1988. Reproductive ecology of greater prairie chickens in Minnesota. Pages 193-239 in A.T. Bergerud and M.W. Gratson, eds. Adaptive strategies and population ecology of northern grouse. Univ. of Minn. Press, Minneapolis.

Tester, J.R. and W.H. Marshall. 1961. A study of certain plant and animal interactions on a native prairie in northwestern Minnesota. Minn. Mus. Nat. Hist. Occas. Pap. 8. Minneapolis.

Westemeier, R.L. and J.E. Buhnerkempe. 1983. Responses of nesting wildlife to prairie grass management on prairie chicken sanctuaries in Illinois. Pages 39-46 in R. Brewer, ed. Proc. 8th N. Am. Prairie Conf. Dept. of Biology, Western MI Univ., Kalamazoo.

Zimmerman, J.L. 1997. Avian community responses to fire, grazing, and drought in the tallgrass prairie. Pages: 167-180, in F.L. Knopf and F.B. Samson, eds. Ecology and conservation of Great Plains vertebrates. Springer, New York.

IV. RESULTS AND PRODUCTS:

This component of the overall study will evaluate effects of burning and grazing on bird distribution and abundance in relationship to prairie habitat type in western Minnesota. Results will complement a major 4-year U.S. Geological Survey study directed by Doug Johnson of the Northern Prairie Wildlife Research Center. That study began in 1998 and is evaluating variables of prairie tract size and landscape matrix on prairie bird abundance and productivity. Svedarsky is a cooperator in that study. This combined information will be essential to prairie managers as they design and carry out management plans to benefit prairie birds. Technical and popular publications will result, including a bulletin entitled, **Birds and Prairies – A management and conservation guide**, scheduled for publication in 2002.

V. TIMETABLE:

Winter-Spring, 1999 -	Identify representative study plots. Identify field assistants.
Late-May, June, 1999 -	Commence bird and vegetation monitoring funded by non-LCMR funds. Hire field assistants. Conduct prescribed burning and coordinate grazing.

July-August 1999 -	Continue bird and vegetation monitoring. LCMR funding commence.
September 1999 -	Tabulate field data and prepare for report(s) at professional and wildlife-oriented meetings. Fine-tune study plan for 2000 field season.
1 February 2000 -	First progress report to LCMR.
Late May-September 2000 -	Repeat of 1999 workplan.
1 February 2001 -	Second progress report to LCMR.
Late May-30 June 2001 -	Repeat of 2000 workplan with fine-tuning.
1 July- September 2001 -	Complete 3rd field season with either LCMR funding (*if a follow-up grant is funded*) or non-LCMR funds.
1 February 2002 -	Third progress report to LCMR. Publication of bulletin, **Fire and Grazing Management of Prairie in Minnesota** combining general results of bird, vegetation, and grazing research.
30 June 2002 -	Final report to LCMR.

VI. ITEMIZED BUDGET FOR PART 3 – PRAIRIE BIRDS

See also Attachment B, Result 3

CATEGORY	YEAR 1 1999-2000	YEAR 2 2000-2001	TOTAL
Project Manager Salary (+ fringe)	$ 6,862	$ 11,438	$ 18,300
Graduate student (+ fringe)	$ 5,280	$ 8,800	$ 14,080
Undergraduate assistant (+ fringe)	$ 2,560	$ 5,120	$ 7,680
Printing & Advertising	-	$ 500	$ 500
Communications (telephone, mail)	$ 250	$ 500	$ 750
Vehicle lease (pickup + ATV)	$ 1,100	$ 1,700	$ 2,800
Local Mileage (@$.325)	$ 650	$ 2,600	$3,250
Other Travel in Minnesota	$ 250	$ 250	$ 500
Travel Outside Minnesota	$ 1,000	$ 1,500	$ 2,500
Office Supplies	$ 250	$ 522	$ 772
Tools and Equipment	$ 500	$ 750	$ 1,500
TOTAL	$ 18,702	$ 33,680	$ 52,632

VII. RESUME OF DANIEL SVEDARSKY, PRINCIPAL INVESTIGATOR FOR PRAIRIE BIRDS

Daniel Svedarsky, Northwest Experiment Station, U of Minnesota,
Crookston, MN 56716 dsvedars@mail.crk.umn.edu
218-281-8129 FAX: 218-281-8050

EDUCATION:

University of Missouri, Columbia, B.S. (1967), Biology
University of Missouri, Columbia, M.S. (1969), Botany (Plant Ecology)
University of North Dakota, Grand Forks. Ph.D. (1979), Wildlife Biology

ACTIVITIES:

Teaching: Since 1969 I have held a faculty position at the Crookston campus of the University of Minnesota. I currently head the Natural Resources Department where I teach Wildlife Ecology and Management, Ecology, Plant Taxonomy, Land Use Planning, Prairie Management, and Integrated Resource Management. I also administer the University's Red River Valley Natural History Area, an 85-acre research, demonstration and environmental education facility which I founded in 1971.

Research: I hold a joint appointment with the Northwest Agricultural Experiment Station, where I conduct research on wildlife and related land use issues as they pertain to prairie and agricultural environments. Past research topics include: Breeding birds of gravel pits, Reproductive ecology of greater prairie chickens in Minnesota, Breeding birds of single-row windbreaks, American kestrel use of nest boxes in agricultural environments, Biological inventory and management of a multi-purpose flood control impoundment, Management and restoration of tallgrass prairie, Wildlife of cultivated wild rice paddies in northwest Minnesota, Integrated management of livestock and prairie chickens on the Sheyenne National Grasslands, currently developing a long-term grazing and burning plan for the Mentor Prairie Wildlife Management Area in Minnesota, and implementing a research/demonstration project on The Nature Conservancy's Pankratz Prairie where grazing will be used as a management tool.

Outreach: I actively provide assistance to various citizen and technical groups on plant identification, and prairie and wetland management. In 1997, I participated in a 3-day Holistic Resource Management Workshop with rancher and agency personnel and hosted a workshop on, "Grazing as a prairie management tool in Minnesota."

Organizations/service to agencies: President, North Central Section, The Wildlife Society, 1989-1990, and member of steering committee for national symposium entitled, "Wildlife Management in 2020; President, North American Wildlife Technology Association, 1988-89; Chair, International Prairie Grouse Technical Council, 1986-87; Current board member, Minnesota Prairie Chicken Society; Technical Advisor - Northern Tallgrass Prairie Project - USFW. 1995-present; Commissioner's Advisory Committee for Scientific and Natural Areas, Natural Heritage, and Nongame Wildlife Programs, MN DNR. 1990-1995; Advisor, Governor's Task Force on Sand and Gravel Reclamation in Minnesota and co-edited resulting MN DNR handbook; Board of Directors, Minnesota Zoo (1988-1992); Endangered Species Committee, MN DNR (1981-1983). Advisor, Critical Areas Program, Minnesota State Planning Agency (1976-1979).

Recent Publications

1. Svedarsky, W.D., T.J. Wolfe, and J.E. Toepfer. 1997. The greater prairie-chicken in Minnesota. MN Wildl. Rep. II. MN DNR, St. Paul. 19 pp.

2. Svedarsky, W.D. and G.L. VanAmburg. 1996. Integrated management of the greater prairie-chicken and livestock on the Sheyenne National Grasslands. Northwest Experiment Station, U. of Minnesota, Crookston. 112 pp.

3. Svedarsky, W.D., C.F. Tydeman, and R.D. Crawford. 1995. Gravel pits as wildlife habitat for wetland wildlife in North America and Europe. Pages 679-683 in J. Bissonette and P. Krausman, eds., Proc. Int. Wildl. Manage. Cong., The Wildlife Society, Bethesda, MD.

Awards:

1. Horace T. Morse - U of MN Alumni Assoc. Award for Outstanding Contributions to Undergraduate Education. 1997.
2. Honorary State Farmer – MN Vocational Agriculture Association. 1996.
3. The Hamerstrom Award - Prairie Grouse Technical Council. 1995.
4. National Stewardship Award – The Nature Conservancy. 1981.

Research Addendum:

Response of Northern Tallgrass Prairie Vegetation to Rotational Versus Season-Long Grazing Systems and Spring Fire

Margaret A. Kuchenreuther
Division of Science and Mathematics, University of Minnesota - Morris

June 30, 2002

Funding for this study provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources.

Abstract

This on-farm research project evaluates the effects of different grazing systems on northern tallgrass prairie plant communities. The grazing systems are as follows: a rapid-rotation system, utilizing 10 paddocks, a rotational system utilizing three paddocks, a rotational system utilizing two paddocks and a pasture that is continuously grazed throughout the season. A manipulative experiment was performed on the farm with the 10-paddock system, which compared vegetation in long-term grazed plots, long-term ungrazed plots, plots released from grazing through establishment of exclosures and ungrazed plots that were burned in the spring. Permanent plots were established on all farms and in all of the experimental treatment areas. Plant frequency and basal cover were used to evaluate community composition and structure. Vegetation quality, as assessed by the frequency of native grasses and forbs versus non-native taxa, was higher on the farms with rotation through 10 or three paddocks than on the farms with little rotation or continuous grazing. The pastures with faster rotation supported more native forbs and hosted significantly fewer ruderal taxa (notably thistles) than did those with little rotation. Native pasture not burned or grazed for more than a decade exhibited a decrease in the richness and frequency of desirable native forbs relative to the adjacent pasture that is grazed with a rapid-rotation system. Burning the unmanaged pasture restored some of the richness of desirable native forbs and replaced the coarse, woody stems of shrubs with tender new sprouts, though it also stimulated the appearance of ruderal species. Release from rapid-rotational grazing through establishment of exclosures produced little measurable effect, except a reduction in frequency of some weedy species. This study raises concerns about the efficacy of continuous grazing in native prairies and shows that a rapid rotational grazing system resulted in the lowest frequency of weedy taxa and the highest frequency of desirable native forbs on the farms surveyed.

Background

Along with climate, fire and grazing by large ungulates were historically important factors influencing the development and maintenance of prairie plant communities (Axelrod 1985). Yet there is much debate about the appropriate way to apply each as a management tool in prairies and a vast literature exists in each area. Among others, see reviews by Collins and Wallace (1990) on the effects of fire, by Painter and Belsky (1993), Dyer *et al.* (1993) and McNaughton (1993) on the effects of grazing, and by Collins *et al.* (1998) and Knapp *et al.* (1998) and on the interactions of the two types of disturbance.

Fire removes litter, allowing better light penetration and restoring some nutrients. It inhibits the growth of woody vegetation, while stimulating the growth of prairie grasses and forbs (dicots). Early spring burns enhance growth, vegetative reproduction and flowering of warm-season native grasses, and help control the invasion of non-native, cool season grasses (Hulbert 1988, Collins and Wallace 1990). Thus, prescribed burns are currently the most important tool used in the restoration and management of remnant prairies.

Unlike a single episode of fire, grazing removes both the standing crop and litter, often repeatedly, throughout the growing season. Grazers also remove biomass much more selectively than does fire, and grazers produce a much patchier form of disturbance than fire through localized trampling of vegetation, mechanical disturbance of the soil, and deposition of urine and feces (Milchunas *et al.* 1988, Huntly 1991). In addition, overgrazing has long been known to reduce the vigor of native plant communities, decrease the abundance of some native species and cause invasion by non-native grasses and weedy dicots (Weaver 1954).

There is much debate about the appropriate way to apply grazing as a management tool in native grassland communities. Much of the discussion surrounds the difference between season-long and various rotational grazing regimes, though stocking rate is also important (Blanchet *et al.* 2000). Proponents of rotational grazing argue that it promotes more even use of forage resources than does continuous grazing by forcing cattle to consume less palatable species. It also allows time for regeneration of the plant community during the time cattle are excluded from a paddock, which should result in a healthier stand. Most of the relevant research on these questions has been conducted well to the west and south of Minnesota (e.g., the tremendous amount of research that has been conducted at Konza Prairie in Kansas, which was recently reviewed by Knapp *et al.* 1998)

Private land owners and natural areas managers alike need guidelines for optimizing tallgrass prairie management. The long-term objective is to develop management recommendations that will simultaneously maximize native prairie plant diversity and productivity, while curtailing invasion by exotics.

This research project sought to address the following questions:

1. What are the effects of different grazing regimes (rotational grazing in different number of paddocks vs. season-long grazing) on vegetation structure and composition in stands of native prairie?

2. What are the effects of release from long-term grazing on vegetation structure and composition?

3. What are the effects of fire on vegetation structure and composition? How does this compare to the effects of grazing?

Specifically, we looked for significant effects of these treatments on:

a. the frequency and relative cover of warm-season, native grasses, such as big bluestem (*Andropogon geradii*), indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparius*) and grama grasses (*Bouteloua curtipendula, B. gracilis and B. hirsuta*).

b. the frequency and relative cover of invasive, non-native, cool-season grasses, such as bluegrass (*Poa pratensis* and *P. compressa*) and smooth brome (*Bromus inermis*).

c. the frequency and relative cover of selected indicator species of native forbs, including reputed grazing increasers, such as yarrow (*Achillea millefolium*), frost aster (*Aster ericoides*), sage (*Artemesia ludoviciana* and *A. frigida*) and Canada goldenrod (*Solidago canadensis*), and decreasers, such as leadplant (*Amorpha canescens*), prairie bush clover (*Lespedeza capitata*), ground plum (*Astragalus crassicarpus*), and blazing star (*Liatris* spp.) (Weaver 1954).

d. the frequency of invasive, non-native weeds such as Canada thistle (*Cirsium canadensis*), plumeless thistle (*Carduus* spp.), leafy spurge (*Euphorbia escula*) and sweet clover (*Melilotus* spp.).

Methods

Study sites:

Four cooperators who have implemented or who intended to implement different types of grazing systems on native prairie were identified. Their grazing systems span the range from season-long grazing to rotational grazing in two to ten paddocks. The study sites were all located on dry glacial ridges, having rocky soils, and dominated by the intermediate height species, little bluestem (*Schizachyrium scoparius*), needlegrasses (especially *Stipa spartea*) and grama grasses (*Bouteloua* spp.), rather than the taller species, big bluestem (*Andropogon geradii*) and indiangrass (*Sorghastrum nutans*).

Elmer farm – Douglas Co., and a modified Savory cell system (Savory 1988) of short-term rotational grazing among 10 paddocks, with 2 additional ungrazed, unmanaged paddocks. This system had been in place for 10 years at the beginning of the study (having replaced season-long grazing of the entire site). This is the site of our manipulative experiments.

Frederickson farm – Pope Co., W 1/2 Sec. 23, T124N R39W, season-long grazing 1999, a 3-paddock system implemented in 2000.

Billehus farm – Pope Co., SE 1/4 Sec. 27, T123N R39W, season-long grazing 1999, a 4-paddock system planned, partially implemented in 2000.

Rutledge farm – Pope Co., NW 1/4 Sec. 10, T124N R39W, season-long grazing in a single large pasture 1999-2001.

Vegetation Sampling:

In 1999, permanent 30 X 50 m plots were established on each farm for the purpose of measuring vegetation. Six plots were established on each farm, with the exception of the Elmer farm where six plots were established in each of four paddocks (two that were being grazed and two that had not been grazed for at least ten years because of their enrollment in the Water Bank program). Each of the farms has the hilly topography characteristic of the glacial moraines upon which they are found; thus, the plant communities they support are heterogeneous and vary with position on the hill slope. Therefore, a number of sampling conventions were employed in an attempt to make possible meaningful comparisons among farms, plots and years. All of the plots were established on or near hilltops to standardize as much as possible the plant community that was being sampled. In an attempt to avoid the error introduced by repeated random sampling in a heterogeneous environment (West and Hatton 1990), sampling was done systematically. In this way roughly the same quadrats were resampled in subsequent years.

In each plot three 50 m transects were established, with endpoints beginning at 8, 16 and 24 m along the 30 m baseline. Along each transect, beginning 2 m from the baseline of the transect, and every 5 m thereafter, a 1/2 m^2 (1m x 1/2 m) quadrat frame was placed on the right-hand side of the line, with its long axis perpendicular to the length of the transect (for a total of 10 quadrats per transect).

Within each quadrat the presence/absence of a list of target taxa (Table 1) was recorded. The decision to score taxon frequency, rather than to attempt to assess canopy cover using another method (e.g. Daubenmire 1959) was based upon the conclusion that taxon frequency is better indicator of community composition over time than is canopy cover, especially in a situation such as this, where grazing by cattle can swiftly and radically change the canopy cover of an area (Hartnett *et al.* 1996). Additionally, West and Hatton (1990) provide evidence of the significant error introduced when different observers repeat cover estimates. As a second way to attempt to insure accuracy of sampling across different groups of observers in different years, we used a limited list of target taxa instead of trying to compile a complete species list of each quadrat. The list included all of the dominant grasses and common annual and perennial non-native grasses. It also included forbs, some of which are noted in the literature as grazing decreasers (e.g. many legumes) and others as grazing increasers (Weaver 1954). Other native forbs were included simply because they were of interest to the author and because they were relatively common and easy to identify (e.g., *Lithospermum* spp. and *Aster sericius*). To further simplify the list, species that could be confused and/ or be difficult to separate after having been eaten by cattle were lumped (e.g. *Stipa spartea*, *S. comata* and *S. viridula*; *Bouteloua gracilis* and *B. hirsuta*; *Lithospermum canescens* and *L. incisium*; *Poa pratensis* and *P. compressa*). Many *Solidago* and *Aster* species were excluded because of the difficulty of identifying them, even to genus, without material in reproductive condition. Plant nomenclature follows the Great Plains Flora Association (1986).

At the same points along the transect where the quadrats were placed, a standard 10-point frame was placed on the left-hand side of the line, with its right-most point at the appropriate meter mark. The cover type intercepted by each point of the 10-point frame also was recorded. The cover classes were: native grass, introduced grass, forb, rock, litter and bare ground.

Each year plots were sampled during the period between the beginning of the last week in July and the end of the second week in August.

Manipulative Experiments:

At the Elmer farm we instituted two different experimental treatments after year one of the study (see schematic diagram, Fig. 1):

Exclosures -- In early spring 2000 half of the long-term grazed plots were fenced off so they could not be grazed. These were maintained for a second year in 2001. The vegetation in these plots was monitored as above.

Burning -- Half of the long-term ungrazed plots were burned on 4 June 2001. The vegetation in these plots was monitored as above. In addition, woody plant stems were sampled in both the ungrazed and burned plots during the summer after the burn to assess the effects of fire on the mortality and regrowth of woody vegetation. Stem counts were made in the same quadrats used to measure plant frequencies. Woody stems were identified and scored for condition: dead, good or sprout (the latter condition applying to stems that lacked corky bark and had obviously been produced during the current growing season).

Data Analysis:

Between farm differences in taxon frequency were tested for significance using the Wilcoxon-Mann-Whitney test (StatXact 4 for Windows 2000). The direction and magnitude of differences in taxon frequency were assessed using the the Hodges-Lehmann estimate of shift parameter (StatXact 4 for Windows 2000).

The results of the experimental treatments at the Elmer farm were visualized using graphs and analyzed using loglinear analysis (Fienberg 1991). Models incorporating year, paddock, treatment and the interaction between these terms were tested to determine which, if any of these factors explained the patterns of taxon frequencies observed (SYSTAT for Windows 1999). Taxa that appeared only rarely in plots were excluded from these analyses because of sample size.

The effect of fire on woody stems was analyzed using the Cochran-Mantel-Haenszel test, controlling for paddock (SAS).

Results

Effects of Grazing Rotation System:

Taxon richness

Taxon richness was similar among farms, with the exception of the Billehus farm, which had lower numbers of native forbs and grazing decreaser forbs at the beginning of the study than were observed on other farms. However, the number of taxa in these categories increased over the course of the study on the this farm after season-long grazing was replaced with rotational grazing (Table 2).

Taxon frequency

Some of the taxa we initially expected to find in these prairies were rare or absent. A positive observation is that the invasive exotics, leafy spurge (*Euphorbia esula*) and Canada thistle (*Cirsium canadense*), were not present in any of the plots surveyed. A negative is that few legume species were found on any of the farms. Only leadplant (*Amorpha canescens*) and purple prairie clover (*Dalea purpurea*) were common. Other species, such as prairie bush clover (*Lespedeza capitata*), ground plum (*Astragalus crassicarpus*) and scurf peas (*Psoralea* spp.), were encountered only rarely or were completely absent from the farms surveyed.

Among farm comparisons of the mean frequencies of individual taxa revealed only a few clear trends associated with the degree of grazing rotation; in general, the farms with the longest grazing duration showed higher average frequencies of exotic species. Plumeless thistle (*Carduus* spp.) and foxtail (*Setaria* spp.) showed a pattern of frequency such that Rutledge >> Billehus> Frederickson = Elmer (Figs. 2 and 3). Thistles and foxtail occurred in 43.7% and 63.9%, respectively, of the quadrats in the continuously grazed pasture at the Rutledge farm (Table 3). This is clear evidence of the deterioration of vegetation quality in this pasture. The two- and three- paddock systems had intermediate levels of exotic species and the rapid-rotation system had the fewest (with the exception of plumeless thistle, which occurred in 11.3% of the quadrats at the Elmer farm and only 3.9% of the quadrats at the Frederickson farm (Table 3). Smooth brome grass (*Bromus inermis*) showed a similar pattern of decrease with increased rotation, where Billehus >> Rutledge = Frederickson > Elmer (Fig. 2).

The ruderal native, prostrate spurge (*Euphorbia* sp.), also reached its highest frequency on the Billehus farm (Fig. 4). The only other native species that showed clear patterns related to grazing rotation were leadplant (*Amorpha canescens*) and side-oats grama (*Bouteloua curtipendula*). The frequency of leadplant decreased with increasing grazing duration, such that Billehus < Rutledge <Frederickson = Elmer, whereas the frequency of side-oats grama increased with grazing duration, Rutledge > Frederickson > Billehus >> Elmer (Fig. 4).

Some exotic species, such as quackgrass (*Agropyron repens*), sweet clover (*Melilotus* spp.), and bluegrass (*Poa* spp.), showed significant differences in frequency between some pairs of farms, but the patterns were not clearly related to the grazing system employed on the farms (Figs. 2 and 3). Native species, such as blazing star (*Liatris* spp.), purple coneflower (*Echinacea angustifolia*), Canada goldenrod (*Solidago canadensis*) and yarrow (*Achillea millefolium*) also had frequencies that were significantly different among farms but again the patterns could not be clearly related to grazing system (Figs. 4 and 5). There were no statistically significant differences among farms in the taxa for which do not appear in Figs. 2-5.

Vegetative Cover

The first obvious result is a high degree of year-to-year variation present in the data (Fig. 6). In all cases, relative cover values for litter are lowest in the first year of the study and increase in the second and third years; there is a concomitant decrease in basal cover of vegetation cover classes as the cover by litter increases. The magnitude of these year-to-year changes generally exceeds the variation seen among farms. The only clear difference among farms is that the Frederickson farm consistently had the lowest cover values for the bare ground / rock category of all the farms surveyed (Fig. 6).

Experimental Treatments at Elmer Farm:

Taxon richness

Taxon richness of native forbs and grazing decreaser forbs was slightly lower in the long-term ungrazed plots than the grazed paddocks. In the grazed paddocks, little change in taxon richness was observed in response to the installation of exclosures. Fire appears to have caused a slight increase in the number of grazing decreaser forb taxa in the burned plots (Table 2).

Taxon frequency

Log-linear analyses reveal that patterns in taxon frequency are explained by paddock, treatment and year effects, as well as by interactions among these variables (Table 4). Consequently, few taxa show trends that can be clearly linked to the application of our manipulative treatments (the remainder showing either low significance of the model that best fit the data or, conversely, producing results that fit the model well but only when a large number of terms are included in the model, rendering a straight-forward analysis of the pattern impossible).

Of the clear trends seen, the largest differences appear to be the result of long-term management of the paddocks. Long-term grazed paddocks had greater frequencies of some ruderal native species, such as prostrate spurge (*Euphorbia* sp.) (Fig. 7), rosette forming native species, such as prairie smoke (*Geum triflorum*) and pussytoes (*Antennaria* sp.) (Fig. 8), sage (*Artemesia frigida*), a grazing increaser (Fig. 9), the native grama grasses (*Bouteloua curtipendula*, *B. hirsuta* and *B. gracilis*) and junegrass (*Koleria cristata*) (Fig. 10), and exotic annual grasses, such as foxtail (*Setaria* spp.) (Fig. 7). (Note that a high degree of variation among years and variation among plots within treatments contribute to low significance of the loglinear model for postrate spurge, foxtail and junegrass.) Long-term ungrazed paddocks had higher frequencies of the native forbs, frost aster (*Aster ericoides*) and ground cherry (*Physalis* spp.) (Fig. 9), of the native grass, prairie dropseed (*Sporobolus heterolepis*) (Fig. 10), and of non-native species, smooth brome grass (*Bromus inermis*) (Fig. 11).

Release from long-term grazing in exclosures caused few measurable changes in plant frequency. Establishment of exclosures lead to a slight increases in the frequency of leadplant (*Amorpha canescens*), a grazing decreaser, and ground cherry (*Physalis* spp.). It also lead to an increase in the frequency of the native annual, flax (*Linum* sp.), though only for the first year after grazing ceased (Fig. 9). Release from grazing eliminated annual foxtail (*Setaria* spp.) from the exclosures and reduced the frequency of prostrate spurge (*Euphorbia* sp.) (Fig. 7).

The burn treatment caused little change in taxon frequencies overall. However, burned plots showed large increases in the frequencies of the ruderals prostrate spurge (*Euphorbia* sp.) and foxtail (*Setaria* spp.) (Fig. 7), and native ground cherry species (*Physalis* spp.) (Fig. 9), a small increase in leadplant (*Amorpha canescens*) frequency (Fig. 9) and decreases in smooth brome grass (*Bromus inermis*), sweet clover (*Melilotus* spp.) and sage (*Artemesia frigida*) frequencies (Figs. 11 and 9).

Bluegrass (*Poa* spp.) frequency showed no pattern (Table 4); it was present in almost every quadrat in the areas sampled.

Vegetative Cover

Comparison of long-term grazed versus long-term ungrazed plots in the initial year of the study reveals that grazing influences vegetation structure by significantly increasing the percent bare ground (26-34% of points intercepting bare ground in grazed plots vs. 5-9% of points intercepting bare ground in ungrazed plots) and significantly decreasing the area covered by litter (24-25% vs. 59-60% of points intercepting litter). Less dramatic differences were seen in percent cover by native grasses, introduced grasses and forbs. A slightly higher proportion of points intercepted native grasses and forbs in long-term grazed plots than in long-term ungrazed plots but these differences were not significant because of the variation among plots (Fig. 12). As seen in the comparison among farms, there are obvious year to year variations in the cover data from the manipulative experiments also. This makes it difficult to draw additional conclusions about the effects of the experimental treatments on basal cover (Fig. 12).

Release from grazing in 2000 and 2001 by establishment of exclosures made no measurable difference in vegetative cover, relative to the trends seen adjacent grazed plots (Fig. 12).

Burning previously ungrazed plots increased the average proportion of points intercepting bare ground (20% bare ground in burned plots vs. 3-9% in unburned, ungrazed plots); however, a high degree of variation among plots rendered this difference statistically insignificant. It made no obvious difference in other basal cover estimates, relative to the trends seen adjacent ungrazed plots (Fig. 12).

Effects of Fire on Woody Plants

Eleven species of woody plants were identified in the sample: aspen (*Populus* sp.), chokecherry (*Prunus virginiana*), gooseberry (*Ribes*sp.), hawthorne (*Crateagus* sp.), leadplant (*Amorpha canescens*), prairie crab (*Pyrus ioensis*), prickly ash (*Xanthoxylum americanum*), rose (*Rosa* sp.) sand cherry (*Prunus pumila* var. *besseyi*), smooth sumac (*Rhus glabra*) and western snowberry (*Symphoricarpos occidentalis*). Only leadplant, rose and western snowberry appeared in sufficient abundance that their response to fire could be analyzed separately. However, an analysis of all species combined was also done (Fig. 13). In all cases fire had a significant negative effect on woody species (Cochran-Mantel-Haenszel test, $p < 0.001$); up to 100 percent of the existing woody stems in a plot were killed (Table 5). However, most species vigorously resprouted from their roots (Fig. 13).

Discussion

What are the effects of different grazing regimes on plant community composition in stands of native prairie?

The results show a strong pattern of increased frequency of exotic species, especially thistles (*Carduus* spp.), foxtail (*Setaria* spp.) and smooth brome grass (*Bromus inermis*) with longer duration of grazing (season-long grazing being the extreme). The frequency of ruderal native species, such as prostrate spurge (*Euphorbia* sp.) also increased with the length of the grazing duration. Season-long grazing promotes continual disturbance of these hilltop areas, where cattle often loaf and seek relief from flies. Continued mechanical disturbance of the soil and repeated defoliation of plants leads to loss of competitive ability of native grasses and forbs, while reduced vegetation height and a high proportion of bare soil encourage the establishment of weedy species (Weaver 1954, Collins 1987).

Few legume species were present on any of the farms. Only leadplant (*Amorpha canescens*) and purple prairie clover (*Dalea purpurea*) were both fairly common. Of these, leadplant was found to show a relationship with grazing regime, decreasing in frequency with increasing grazing duration. This is consistent with its classification as a grazing decreaser (Weaver 1954). Perhaps the long-term grazing histories of all of these pastures explains the overall lack of legume species observed, cattle having selectively grazed them and gradually eliminated them from the community.

Side-oats grama (*Bouteloua curtipendula*) was the only native grass whose frequency showed a strong correlation with grazing duration. Its frequency increased as grazing duration increased. Weaver (1954) designates it as a grazing increaser species. Perhaps it is better able than most other native grasses to withstand the repeated defoliation it encounters under continuous grazing.

Relative basal cover showed no consistent relationship to the grazing system employed because year to year variation was greater than the variation among farms.

The source of the year to year variation is not clear. It could be attributable to variation in measurements made by different teams of observers. However, all groups of observers received training and were periodically monitored for accuracy. Nonetheless, only two observers were present across all three years of the study. A more reasonable explanation could be weather differences among years. However, weather data from the 1999-2001 growing seasons were examined but no extreme patterns, which might be responsible for such variation, were identified. (Data not presented but available from the NOAA web site [http://cdo.ncdc.noaa.gov] for the closest reporting station, Alexandria, MN [Coop ID = 210110].)

The general conclusions of this study concur with the results of a number of other studies of grazing systems in other parts of the tallgrass prairie province. These studies found little effect of the regime on standing crop and the dominance of broad categories of vegetation (e.g., tall grasses, midgrasses, short grasses and forbs) (McIlvain and Savage 1951; Owensby *et al.* 1973; Thurow *et al.* 1988; Gillen *et al.* 1998). However, these studies did not directly address the problem of invasion by exotic species, which was found in this study on farms that allow cattle access to the same pasture for long periods of time.

What are the effects of release from long-term grazing on plant community composition?

Plots on the Billehus farm showed a slight increase in taxon richness in the 2000-2001 growing seasons after a switch from heavy, season-long grazing to rotation between two paddocks. Apparently some taxa were able to grow to recognizable size and/or increase in number when they were released from continuous grazing.

In the manipulative experiment on the Elmer farm, release from grazing most noticeably reduced the frequency of some ruderal taxa. This is to be expected as plots are protected from disturbance by cattle, the canopy closes, litter accumulates and less light reaches the ground. Collins (1987) and Willms *et al.* (1990) also found greater proportions of annual weeds in grazed areas vs. exclosures. Though not observed to a significant extent over the short time frame of this experiment, over the long term the percent of bare ground in the exclosures would be expected to decrease from the 26-35% present at the beginning of the experiment to the 5-9% seen in the ungrazed paddocks. Similar proportions of bare ground were observed by Vinton et al. (1993) in patches that were grazed or left ungrazed by bison.

While comparison of long-term grazed and long-term ungrazed paddocks and the results of Kucera (1956) predict a decrease in the frequency of rosette forming species following a release from grazing, this was not observed during the two years the exclosures were followed.

It is very possible that two years of release from grazing is not sufficient to make a significant change in the frequencies of native perennials. Though we did not document vegetation height or the amount of sexual reproduction by species in our sample plots, casual observation suggests that release from grazing increased both.

Increased height should lead to increased plant vigor, and increased flowering may lead to recruitment of new individuals, ultimately leading to positive changes in the frequency of native perennials.

In their comparison of exclosures to nearby grazed areas in mixed-grass prairies of southwestern North Dakota, Brand and Goetz (1986) found mixed results. At some sites grass and forb abundances were the same inside and outside of exclosures but at others there were marked differences between the treatments. Time since release from grazing and differences in edaphic conditions were invoked to explain the differences among sites. One outcome of their study that parallels the results found here is the greater success of *Bouteloua* in grazed areas.

Overall, the release from long-term grazing produced few significant effects. Perhaps either a longer period of release from grazing would be required to see changes, or the rapid-rotation system used on the Elmer farm, and the higher quality of vegetation it appears to produce, responds less dramatically to release from grazing than would a pasture with a history of continuous grazing.

What are the effects of fire on plant community composition? How does this compare to the effects of grazing?

Long-term experiments at Konza prairie in Kansas consistently show that spring burning increases the dominance of warm season grasses, which form the matrix of the prairie. (See Collins and Wallace [1990] and Knapp *et al.* [1998] for a review of the many relevant studies.) In this experiment burning did not measurably increase the basal cover of native grasses. Neither did it reduce basal cover by litter or by introduced grasses. It did, however, increase the proportion of points intercepting bare ground to a level approaching that seen in the long-term grazed plots. It also reduced litter depth (pers. obs.). These changes were accompanied by an increased frequency of some ruderal taxa. However, this effect is expected to be short-lived if fire is not repeated in the burned plots. (Gibson and Hulbert 1987). Perhaps longer term observations or more than a single episode of fire would be required to see changes in these variables.

The most pronounced effect of fire was its effectiveness at killing the above ground portions of shrubs. This is very different than the effect of grazing, since cattle often leave the coarse stems of woody plants untouched. Though the fire did not completely kill the shrubs, and they vigorously resprouted almost immediately, their tender new shoots would be much more palatable to grazers than were the woody stems before the fire. Therefore, spring fire combined with grazing may provide a way to control shrub dominance in prairies. Further study of these idea is warranted. In prairies where grazing is not a possibility, repeated fire could reduce shrub dominance by repeatedly depleting the root reserves of woody plants.

Limitations of study conclusions

It is important to note that the on-farm research approach employed in this study imposed several constraints on this research. One was the inability to replicate the grazing system research; few farmers in our area are currently employing any system of rotational grazing on their native pastures. Others include differences in the topography, soil type and grazing histories of the farms. Finally, each cooperator has his own way of managing his grazing system. The cooperators set their stocking rates, we did not. Nor could we control the dates when grazing began in the spring and ended in the fall. Therefore, the results of the comparison among grazing systems should be interpreted with caution. They could potentially be the results of one or more of the uncontrolled variables above, rather than grazing system per se, and may not be generalizable to other farms.

Implications for Pasture Management

Other published research indicates that both grazing and fire, and ideally a combination of both, can be used to maintain the diversity of prairie plant communities (see especially Knapp *et al.* 1998). It also shows that complete neglect (Gibson and Hulbert 1987) or excessive grazing will lead to the long-term erosion of the quality of prairie vegetation (Weaver 1954; Kucera 1956). This study, though not documenting dramatic effects of different grazing systems or spring fire, concurs with these conclusions.

In this study vegetation quality, as assessed by the frequency of native grasses and forbs versus non-native taxa, was higher on the farms with rotation through 10 or three paddocks than on the farm with rotation through only two paddocks or that with continuous grazing. The pastures with faster rotation supported more native forbs and hosted significantly fewer ruderal taxa (notably thistles) than did those with little or no rotation. The unmanaged pasture exhibited a decrease in the richness and frequency of desirable native forbs relative to adjacent pasture. Burning this pasture restored some of the richness of desirable native forbs and replaced the coarse, woody stems of shrubs with tender new sprouts, though it also stimulated the appearance of ruderal species. Establishment of exclosures in grazed pasture produced little measurable effect, except reduction in frequency of some weedy species.

However, none of the pastures had the taxon richness expected, based upon experience at local prairies that have a long history of protection (Kuchenreuther, unpubl. data). Especially lacking were legumes. Many years of season-long grazing by cattle has been shown to cause the loss of species from prairies (Weaver 1954; Kucera 1956). All of the pastures in this study were routinely grazed below the recommended height for warms season grasses, at least in the areas we sampled (pers. obs.). We often observed that the swards on these hilltops were grazed to a height of 5 cm or less, when the NRCS recommendation for minimum stubble height of warm season grasses is 5 cm for side-oats grama (*Bouteloua curtipendula*), 7.5 cm for little bluestem (*Schizachyrium* *scoparius*), and 15 cm for big bluestem (*Andropogon gerardii*) and indiangrass (*Sorghastrum nutans*) (Blanchet, *et al.* 2000). This indicates the need to move cattle more frequently or to reduce stocking rates on all of the farms.

The results of this study raise concerns about the efficacy of continuous grazing in native prairies, at least on those with shallow soils. Continuous grazing appears to promote high frequencies of noxious weeds and reduced frequencies of desirable native forbs, relative to levels found on prairies that are rotationally grazed. Knowledgeable and careful application of appropriate grazing and fire regimes are necessary if we are to protect this important component of our natural heritage. Further implementation and monitoring of rotational grazing systems is warranted.

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Table 1. Target species. Legend: DN = decreaser native, IN = increaser native, N = native, E = exotic.

Species	Status	Species	Status
Forbs		**Grasses**	
Alfalfa (*Medicago sativa*)	E	Big bluestem (*Andropogon gerardii*)	N
Birdsfoot violet (*Viola pedatifida*)	N	Bluegrass (*Poa* spp.)	IN/E
Blazing star (*Liatris aspera*)	DN	Dropseed (*Sporobolus heterolepis*)	N
Blazing star (*Liatris punctata*)	DN	Foxtail (*Setaria* spp.)	E
Canada goldenrod (*Solidago canadensis*)	IN	Grama grasses (*Bouteloua* spp.)	N
Canada thistle (*Cirsium canadense*)	E	Indian grass (*Sorghastrum nutans*)	N
Common ragweed (*Ambrosia artemisiifolia*)	IN	Junegrass (*Koleria cristata*)	N
Coneflower (*Echinacea angustifolia*)	DN	Little bluestem (*Schizachrium scoparius*)	N
Flax (*Linum* spp.)	N	Needlegrasses (*Stipa* spp.)	N
Fleabane (*Erigeron* spp.)	IN	Quackgrass (*Agropyron repens*)	E
Flodman's thistle (*Cirsium flodmanii*)	N	Sandreed grass (*Calamovilfa longifolia*)	N
Frost aster (*Aster ericoides*)	IN	Side Oats Grama (*Bouteloua curtipendula*)	N
Ground cherry (*Physalis* spp.)	IN	Smooth brome grass (*Bromus inermis*)	E
Leadplant (*Amorpha canescens*)	DN		
Leafy spurge (*Euphorbia esula*)	E		
Milk vetch (*Astragalus* spp.)	DN		
Missouri goldenrod (*Solidago missouriensis*)	IN		
Mullein (*Verbascum thapsus*)	E		
Pasque flower (*Anemone patens*)	N		
Plumeless thistle (*Carduus spp.*)	E		
Pomme de Terre (*Psoralea esculenta*)	DN		
Prairie clover (*Dalea* spp.)	DN		
Prairie smoke (*Geum triflorum*)	N		
Prostrate spurge (*Euphorbia* sp.)	IN		
Puccoon (*Lithospermum* spp.)	N		
Pussytoes (*Antennaria* spp.)	IN		
Rose (*Rosa* spp.)	N		
Sage (*Artemesia frigida*)	IN		
Sage (*Artemesia ludoviciana*)	IN		
Silky aster (*Aster sericeus*)	N		
Silvery scurf pea (*Psoralea argophylla*)	DN		
Stiff goldenrod (*Solidago rigida*)	N		
Sweet clover (*Melilotus* spp.)	E		
Vervain (*Verbena* spp.)	IN		
Western ragweed (*Ambrosia psilostachya*)	N		
Western snowberry (Symphoricarpos occidentalis)	S		
Whorled milkweed (*Asclepias verticillata*)	N		
Yarrow (*Achillea millefolium*)	IN		

Table. 2 Taxon richness over time. The total number of target taxa in several categories recorded in permanent plots each year at each site (or in each treatment area at the Elmer farm). Headings in the first row indicate when different treatments or grazing regimes were applied. Note that the grazing decreaser forb category is a subset of all native forbs.

Category		Elmer LT grazed 1999-2001	Elmer LT grazed 1999 exclosures installed 2000-2001	Elmer LT ungrazed 1999-2001	Elmer LT ungrazed 1999-2000 burned 2001	Frederickson 3 paddocks implemented 2000-01	Billehus 2 paddocks implemented 2000-01	Rutledge season-long 1999-2001
Native forbs								
	1999	27	25	24	24	28	19	26
	2000	27	27	24	23	28	23	27
	2001	27	26	23	24	28	26	26
Grazing decreaser forbs								
	1999	7	4	5	5	7	2	5
	2000	6	6	5	4	7	4	6
	2001	7	5	6	8	8	7	7
Native grasses								
	1999	8	9	8	9	8	7	7
	2000	9	9	9	10	8	7	8
	2001	8	9	8	8	8	8	8
Exotics								
	1999	8	9	8	10	8	10	9
	2000	10	8	10	7	8	11	9
	2001	10	8	10	9	11	10	11

Table 3. Percentage of 1/2 m^2 quadrats sampled (180 total at each farm) that contained three common exotic species during the 2001 growing season. To make a meaningful comparison possible, only data from plots at the Elmer farm in which grazing continued as usual were included in the modified Savory cell system category.

Species	Modified Savory cell system	3-paddock system	2-paddock system	Continuous grazing
Smooth brome grass	2.8	35	70.6	13.1
Foxtail	17.1	27.4	21.6	63.9
Plumeless thistle	11.3	3.9	15.5	43.7

Table 4. Results of log-linear analyses. Models incorporating year, paddock, treatment and the interaction between these terms were tested to determine which, if any of these factors explained the patterns of taxon frequencies observed over the course of the experiment. Values listed under the headings Main Effect and Interaction are the probabilities associated with each variable; an X indicates that the particular term was not included in the model of best fit. In the Significance column, a high probability value indicates that the model chosen fits the data well. Taxa that appeared only rarely in plots were excluded from these analyses because of sample size (indicated by ~).

Table 4. Log-linear Analyses

		MAIN EFFECT			INTERACTION			SIGNIFICANCE		
SPECIES		PADDOCK	TREAT.	YEAR	PADDOCK *TREAT.	PADDOCK *YEAR	TREAT. *YEAR	PEARSON CHI-SQUARED	D.F.	PROB.
Alfalfa (Medicago)	E	~	~	~	~	~	~	~	~	~
Birdsfoot violet (Viola)	N	0.0001	0.0000	0.0003	0.0000	X	X	15.9472	14	0.3166
Blazing star (Liatris aspera)	DN	0.0028	X	0.0360	X	0.0084	X	3.6857	5	0.59549
Blazing star (Liatris punctata)	DN	X	0.0000	X	X	X	X	7.0328	8	0.5331
Canada goldenrod (S. canadensis)	IN	0.0000	0.0000		0.0000			231.484	16	0.1098
Canada thistle (Cirsium canadense)	E	~	~	~	~	~	~	~	~	~
Common ragweed (A. artemisiifolia)	IN	X	X	0.0000	X	X	X	22.7296	16	0.1212
Coneflower (Echinacea)	DN	~	~	~	~	~	~	~	~	~
Flax (Linum spp.)	N	X	0.0000	0.0000	X	X	X	12.9137	12	0.3754
Fleabane (Erigeron spp.)	IN							36.083	11	0.0002
Flodmans thistle (C. flodmanii)	N	0.0000	0.0105	X	X	X	X	21.0561	18	0.2766
Frost aster (Aster ericoides)	IN	0.0026	0.0432	0.0114	0.0360	0.0239	X	9.4652	8	0.3046
Ground cherry (Physalis spp.)	IN	0.0000	0.0055	0.0055	X	X	0.0209	11.4094	10	0.3265
Leadplant (Amorpha)	DN	0.0000	0.0000	X	0.0000	X	X	9.687	16	0.8824
Leafy spurge (Euphorbia escula)	E	~	~	~	~	~	~	~	~	~
Milk vetch (Astragalus spp.)	DN	X	X	0.0097	X	X	X	12.869	11	0.3020
Missouri goldenrod (S. missouriensis)	IN	X	X	X	X	X	X	152.845	17	0.0000
Mullein (Verbascum)	E	~	~	~	~	~	~	~	~	~
Pasque flower (Anemone patens)	N	X	X	X	X	X	X	28.6609	18	0.0527
Plumeless thistle (Carduus sp.)	E	X	X	X	X	X	X	36.3723	17	0.0041
Pomme de Terre (Psoralea esculenta)	DN	~	~	~	~	~	~	~	~	~
Prairie clover (Dalea spp.)	DN	X	0.0012	X	X	X	X	17.4232	20	0.6254
Prairie smoke (Geum triflorum)	N	0.0000	0.0000	X	0.0012	X	X	10.493	16	0.8396
Prostrate spurge (Euphorbia sp.)	IN	0.0205	0.0000	0.0000	0.0091	X	0.0000	3.2475	4	0.5173
Puccoon (Lithospermum spp.)	N	0.0001	0.0000	0.0020	0.0010	X	X	15.3817	14	0.3526
Pussytoes (Antennaria spp.)	IN	0.0000	0.0000	X	0.0001	X	X	8.921	15	0.8816
Rose (Rosa spp.)	N	0.0000	0.0000	X	0.0000	X	X	10.8987	16	0.8157
Sage (Artemesia frigida)	IN	0.0000	0.0000	0.0009	0.0000	0.0000	X	5.0999	7	0.6478
Sage (Artemesia ludoviciana)	IN	0.0004	0.0000	X	X	X	X	7.3711	12	0.8322

Table 4. Log-linear Analyses, con't.

		MAIN EFFECT			INTERACTION			SIGNIFICANCE		
SPECIES		PADDOCK	TREAT.	YEAR	PADDOCK *TREAT.	PADDOCK *YEAR	TREAT. *YEAR	PEARSON CHI-SQUARED	D.F.	PROB.
Silky Aster (Aster sericeus)	N	0.0003	0.0001	X	0.0000	X	X	1.4831	16	0.5371
Vervain (Verbena spp.)	IN	0.0473	X	X	X	X	X	1.9293	6	0.9261
Western ragweed (A. psilostachya)	N	0.0000	0.0000	0.0002	0.0000	X	X	6.6094	14	0.9487
W. snowberry (Symphoricarpos occidentalis)	S	0.0000	0.0000	X	0.0000	X	X	6.0418	16	0.9876
Whorled milkweed (A. verticillata)	N	0.0000	0.0000	0.0000	0.0000	0.0002	X	16.7689	8	0.0326
Yarrow (Achillea)	IN	0.0000	0.0000	X	0.0000	X	X	5.3407	14	0.9805
Big bluestem (Andropogon gerardii)	N	0.0098	0.0000	0.0001	0.0095	X	0.0044	9.5466	8	0.2983
Bluegrass (Poa spp.)	IN/E	X	0.9831	X	X	X	X	3.1363	20	0.9999
Dropseed (Sporobolus heterolepis)	N	0.0064	0.0071	X	0.0019	X	X	3.5529	9	0.9383
Foxtail (Setaria spp.)	E	X	0.0000	0.0000	X	X	0.0005	11.0038	9	0.2754
Grama grass, blue/ hairy (Bouteloua)	N	X	0.0000	0.0000	X	X	X	9.0114	14	0.8303
Indian grass (Sorghastrum nutans)	N	0.0114	0.0003	X	0.0020	X	X	16.138	14	0.3050
Junegrass (Koleria cristata)	N	0.0012	0.0000	X	0.0011	X	X	11.2179	8	0.1897
Little bluestem (Schizachrium)	N	0.0000	0.0001	X	X	X	X	29.4853	20	0.0786
Needlegrasses (Stipa)	N	X	0.0000	0.0000	X	X	0.0000	11.8732	12	0.4559
Quackgrass (Agropyron repens)	E	0.0096	0.0001	X	X	X	X	36.5312	17	0.0039
Sandreed grass (Calamovilfa)	N	X	X	X	X	X	X	15.5945	4	0.0036
Side Oats Grama (B. curtipendula)	N	0.0000	0.0000	X	0.0000	X	X	8.2235	16	0.9419
Smooth brome grass (Bromus inermis)	E	X	0.0000	0.0159	X	X	X	9.3109	13	0.7491

Table 5. Mortality of woody stems in burned vs. unburned plots. The proportions shown below were calculated by dividing the number of dead stems in a plot by the total number of woody stems assumed to have been in the plot before the burn treatment was applied (i.e., the sum of stems scored as dead and good; sprouts were excluded from the total because they emerged post-fire). The ranges shown reflect the variation observed among the six plots sampled.

	Burned		**Unburned**	
Species	Range	Mean	Range	Mean
Amorpha	0.05 - 1.00	0.50	0.10 - 0.25	0.19
Rosa	0.21 - 1.00	0.53	0 - 0.17	0.16
Symphoricarpos	0.46 - 1.00	0.78	1.08 - 0.31	0.20
All species	0.33 - 1.00	0.70	0.11 - 0.27	0.17

Figure 1. Schematic of Elmer farm experimental design. Six sample plots were established in each of the four paddocks shown (of twelve total paddocks in the modified Savory cell grazing system). Two of these paddocks were included in the grazing rotation, two had remained ungrazed and unmanaged for at least ten years prior to the beginning of the experiment. Plots were established in 1999. In 2000 exclosures were established around half of the plots in the grazed paddocks; these were maintained through the 2001 growing season. In 2001 half of the plots in the ungrazed paddocks were burned in early June.

ELMER FARM SCHEMATIC (not to scale)

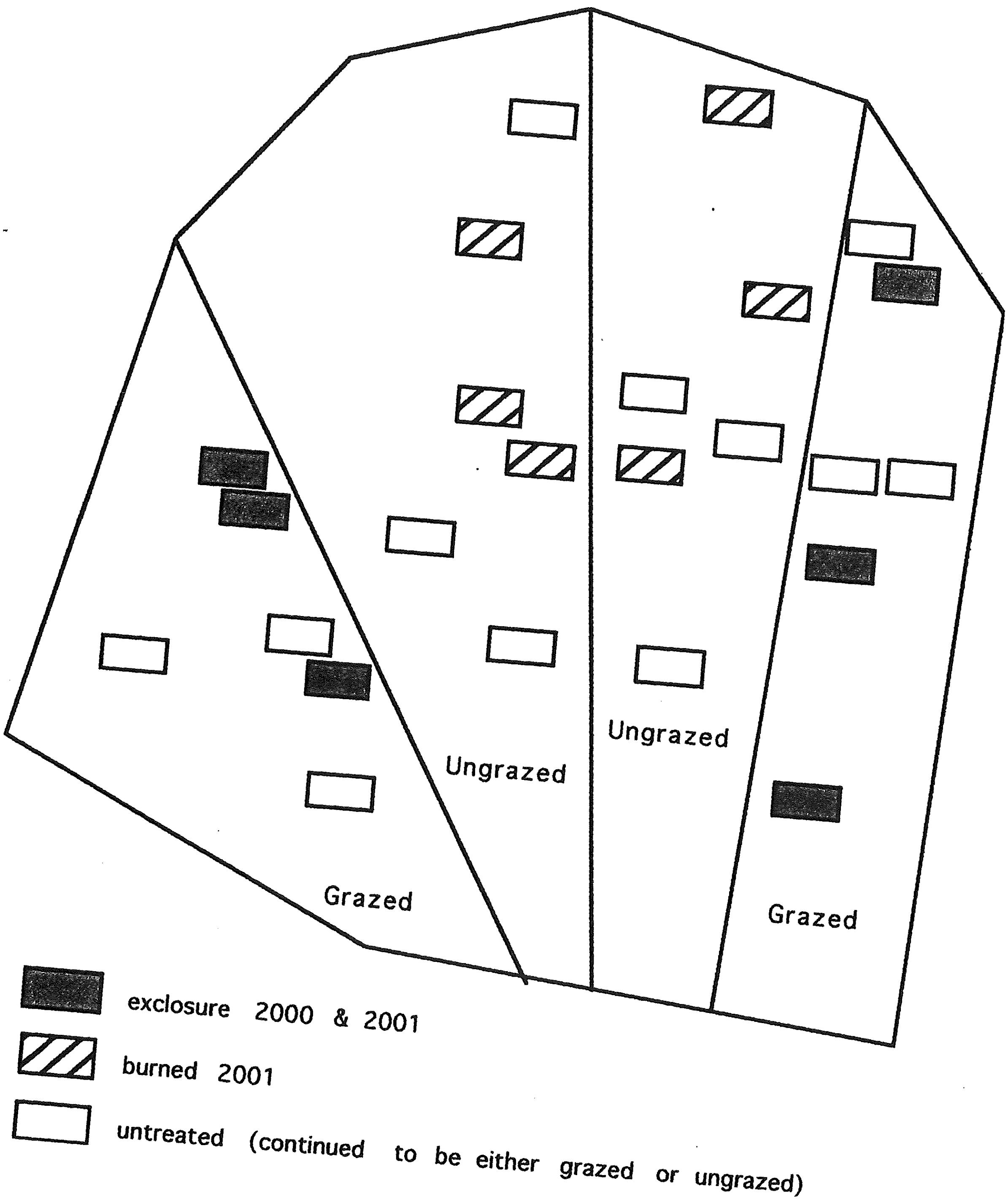
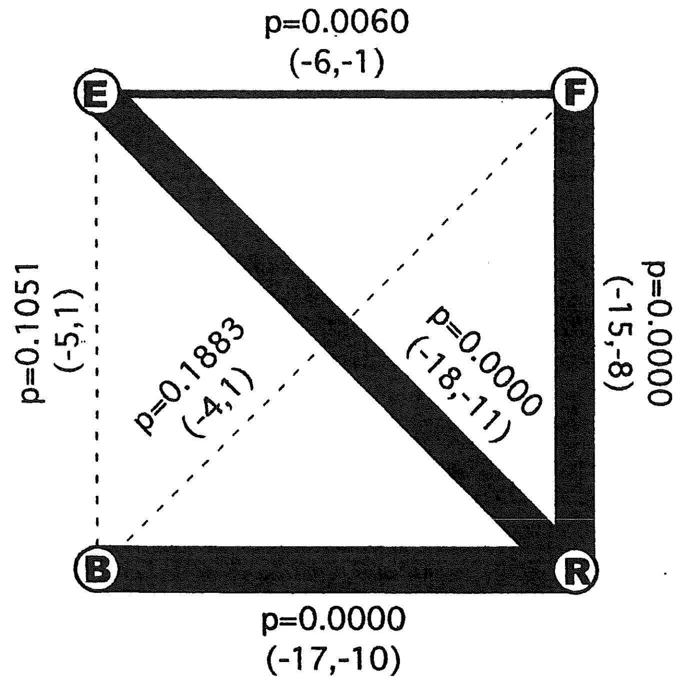
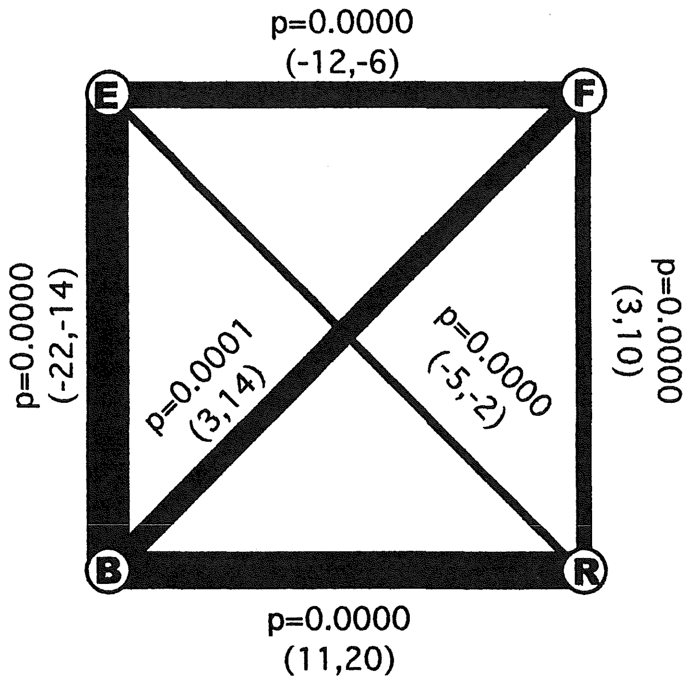


Figure 2. Comparison of the frequencies of non-native grasses on farms with different grazing systems. Pairwise differences between farms in the frequencies of individual taxa were tested for significance using the Wilcoxon-Mann-Whitney test. The direction and magnitude of differences in taxon frequency were assessed using the the Hodges-Lehmann estimate of shift parameter. On this diagram letters correspond to farms employing different grazing systems. E = Elmer (rapid rotation through 10 paddocks), F = Frederickson (rotation through three paddocks), B = Billehus (rotation through two paddock), R = Rutledge (continuous grazing). The size of the bar connecting two farms corresponds to the magnitude of difference in the frequencies of a particular taxon between the two farms. Dotted lines signify no statistically significant difference in taxon frequency between farms. Near the center of each line are two sets of numbers. The top number indicates the level of statistical significance of the difference between farms. The bottom pair of numbers is the confidence interval surrounding the mean parameter shift in taxon frequency between the two farms. All diagrams are read left to right and top to bottom. For example, the mean parameter shift in the frequency of *Setaria* spp. between the Elmer farm and the Rutledge farm is -15 (signified by a wide bar). This means that the two frequencies are very different (no significant difference would result in a parameter shift near zero). The negative values of the confidence interval show that the mean frequency of *Setaria* spp. on the Elmer (to the top and left of Rutledge) is less than than on the Rutledge farm.

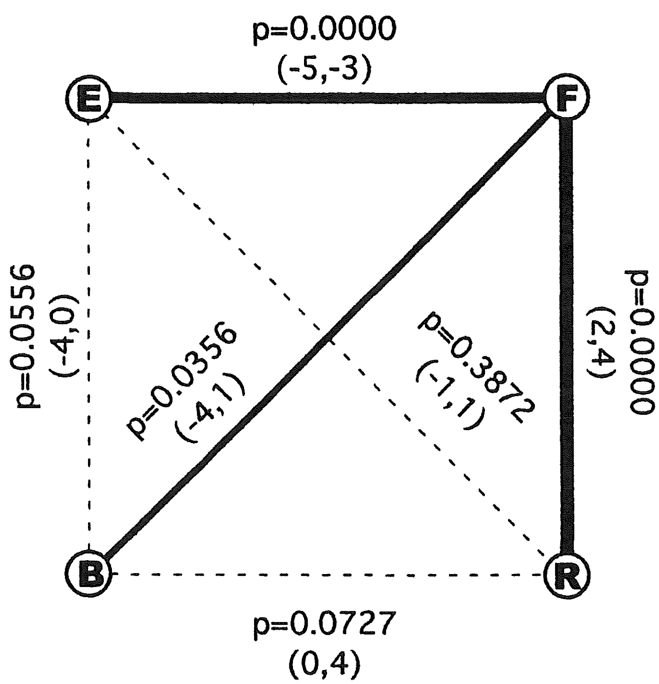
Setaria spp.



Bromus inermis



Agropyron repens



Poa spp.

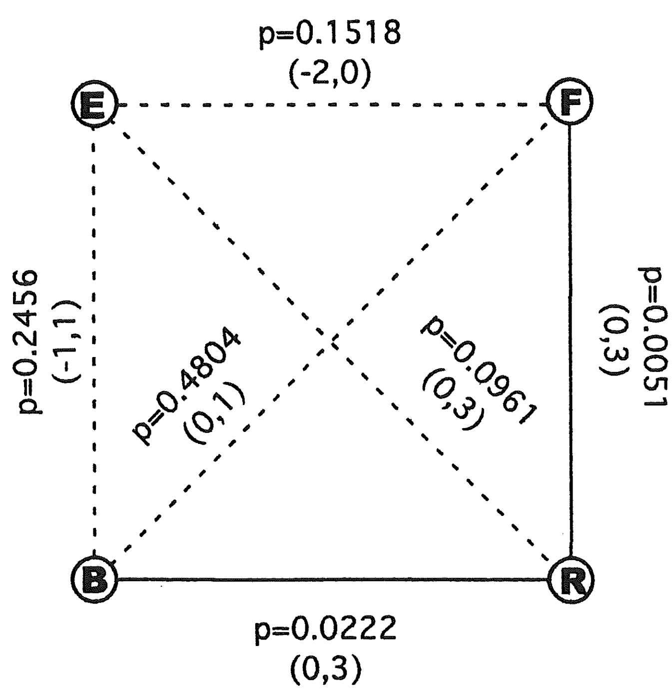
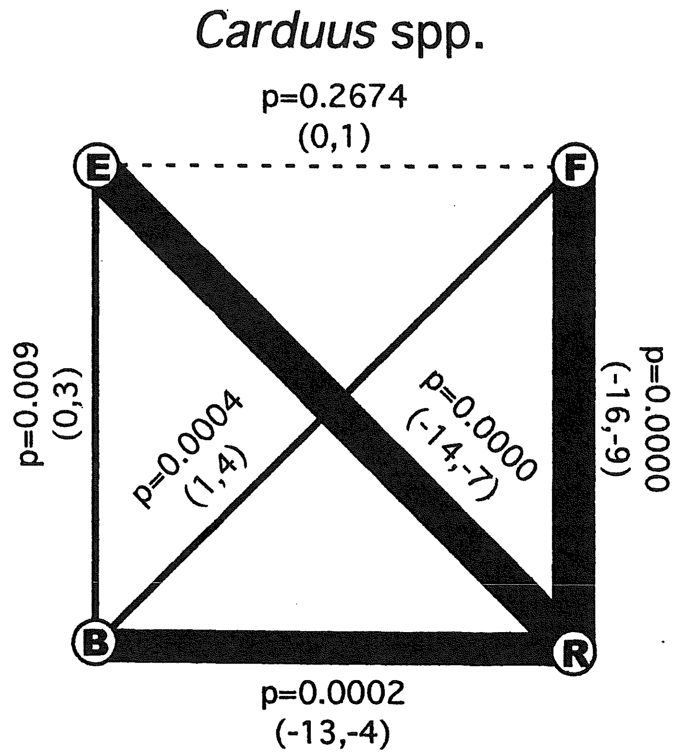
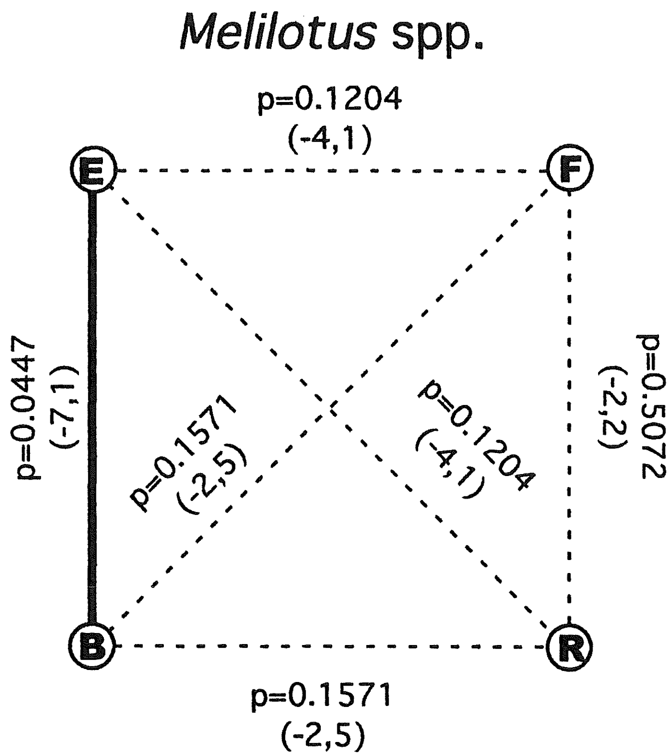


Figure 3. Comparison of the frequencies of non-native forbs on farms with different grazing systems. See the caption of Fig. 2 for an explanation of how to interpret the figure.



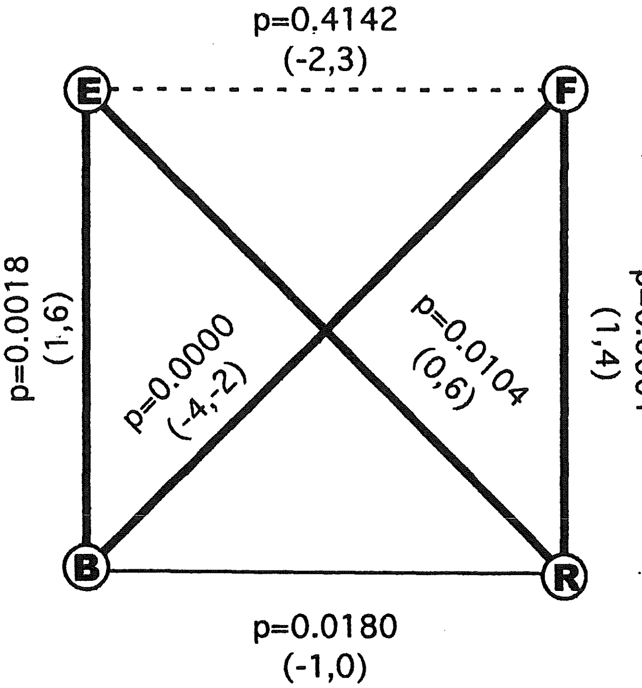
Carduus spp.
p=0.2674
(0,1)
E
F
B
R
p=0.009
(0,3)
p=0.0004
(1,4)
p=0.0000
(-14,-7)
p=0.0000
(-16,-9)
p=0.0002
(-13,-4)



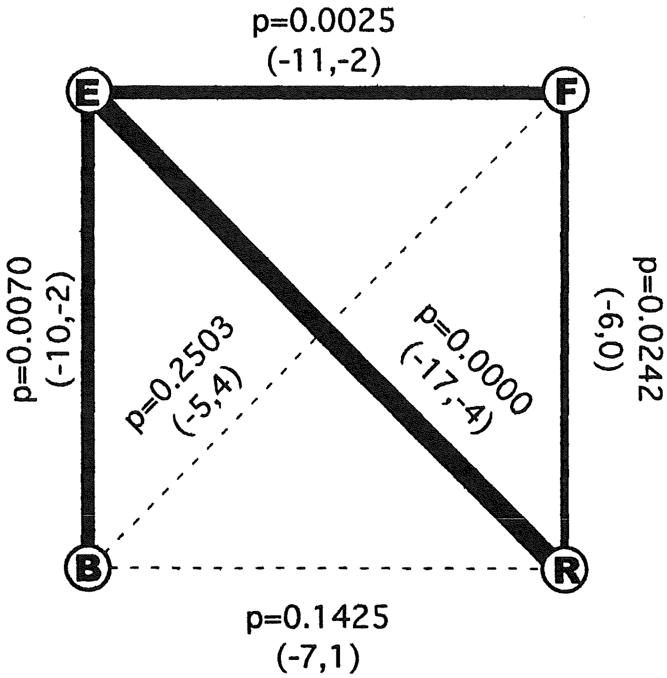
Melilotus spp.
p=0.1204
(-4,1)
E
F
B
R
p=0.0447
(-7,1)
p=0.1571
(-2,5)
p=0.1204
(-4,1)
p=0.5072
(-2,2)
p=0.1571
(-2,5)

Figure 4. Comparison of the frequencies of native species on farms with different grazing systems. See the caption of Fig. 2 for an explanation of how to interpret the figure.

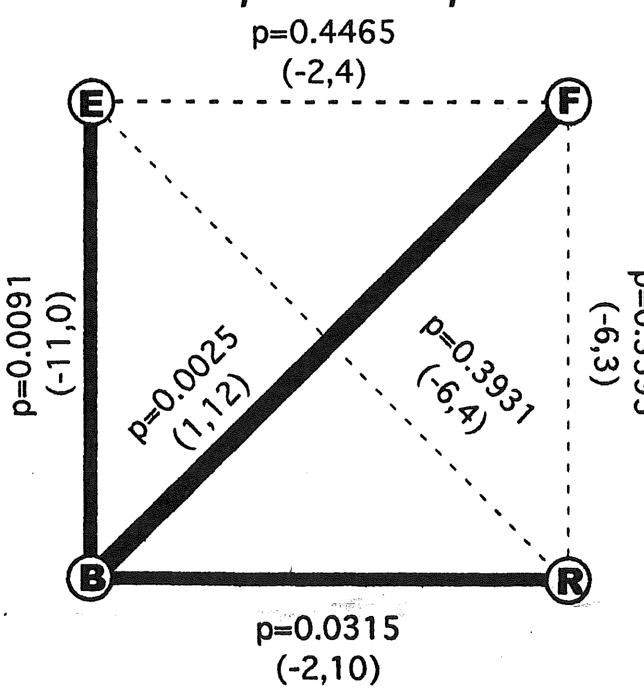
Amorpha canescens



Bouteloua curtipendula



Euphorbia sp.



Achillea millefolium

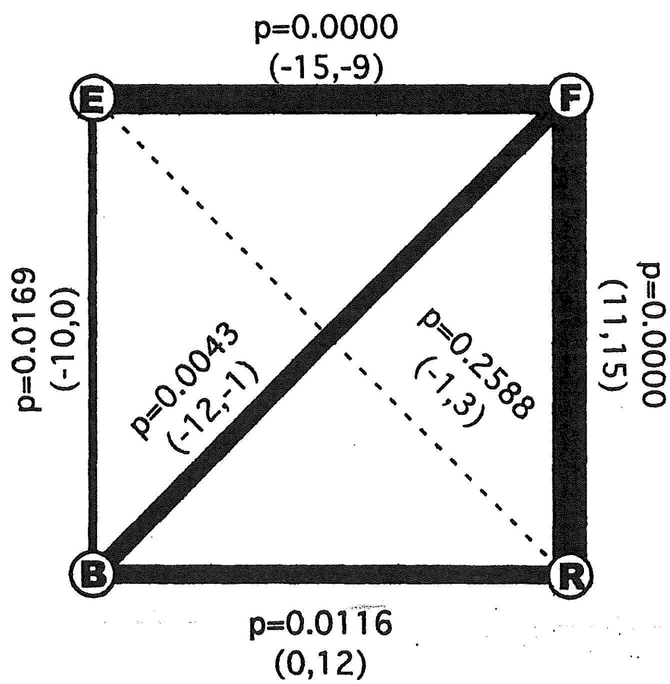


Figure 5. Comparison of the frequencies of native species on farms with different grazing systems, con't. See the caption of Fig. 2 for an explanation of how to interpret the figure.

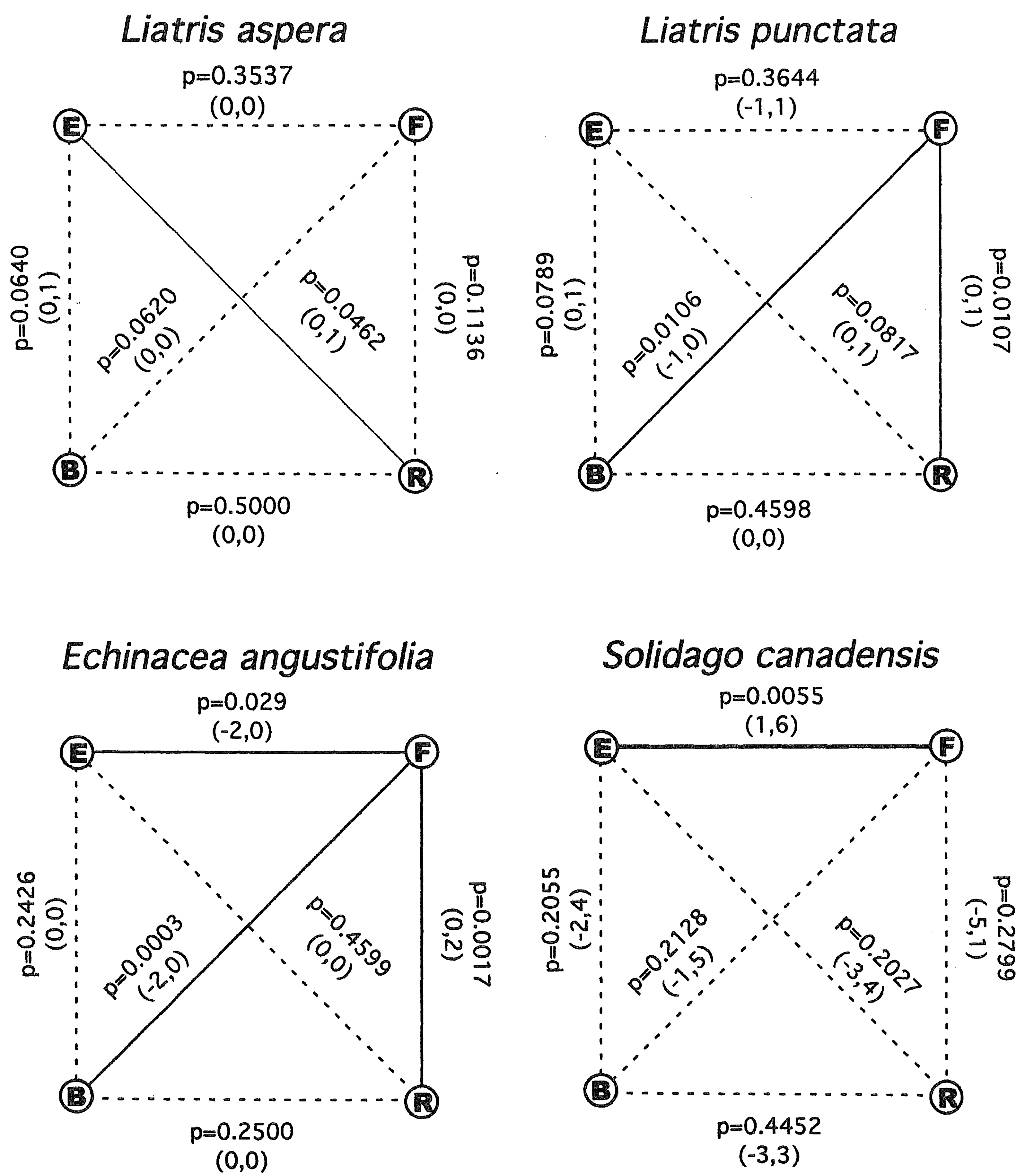
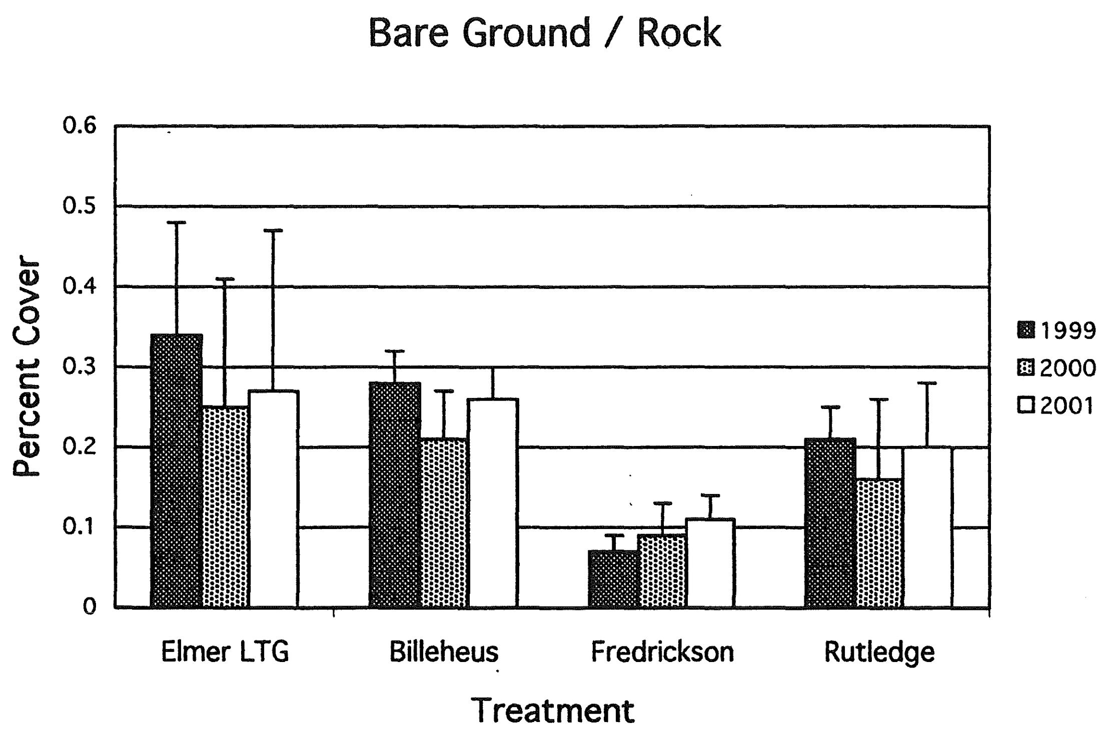
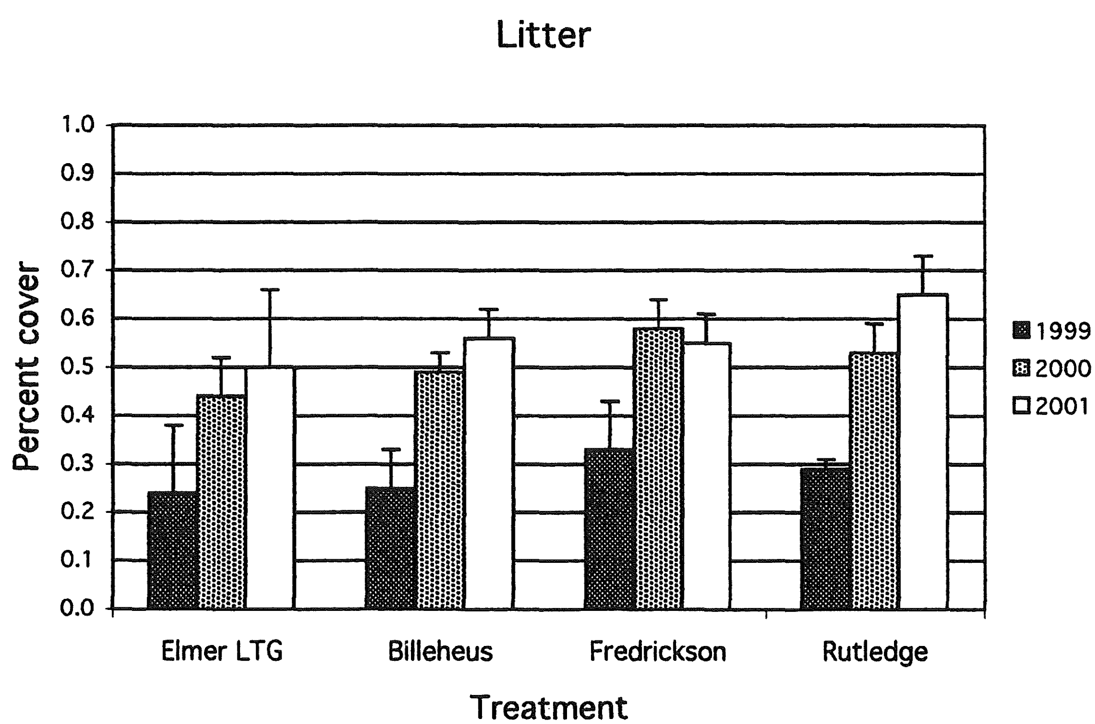
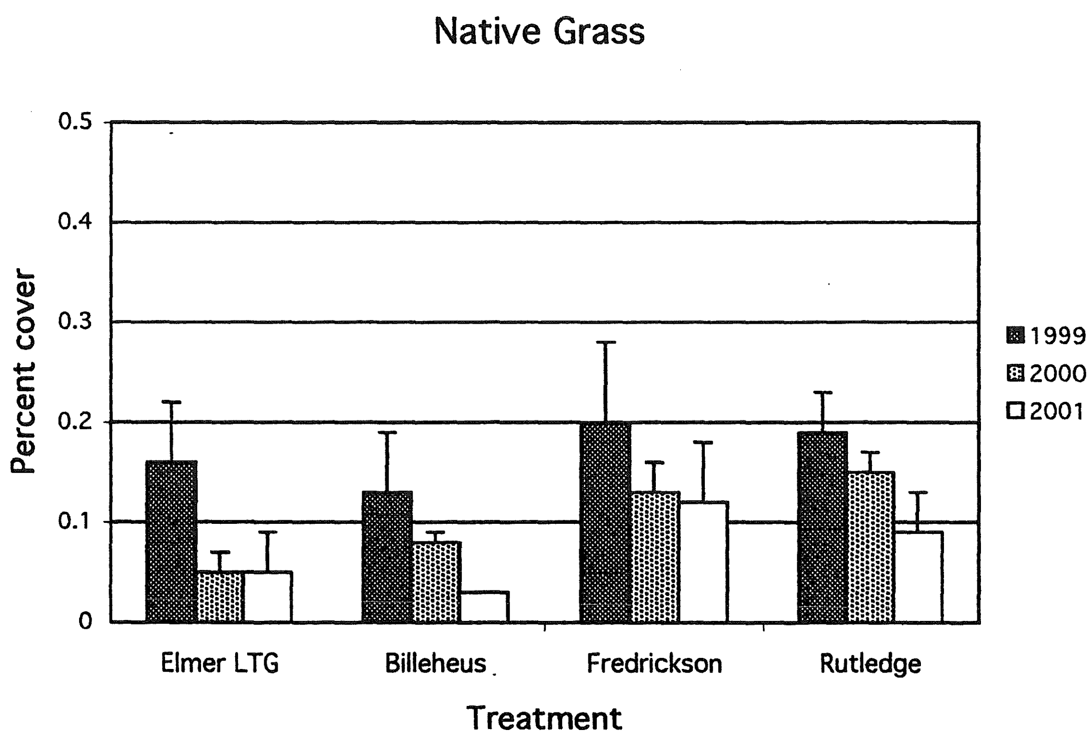
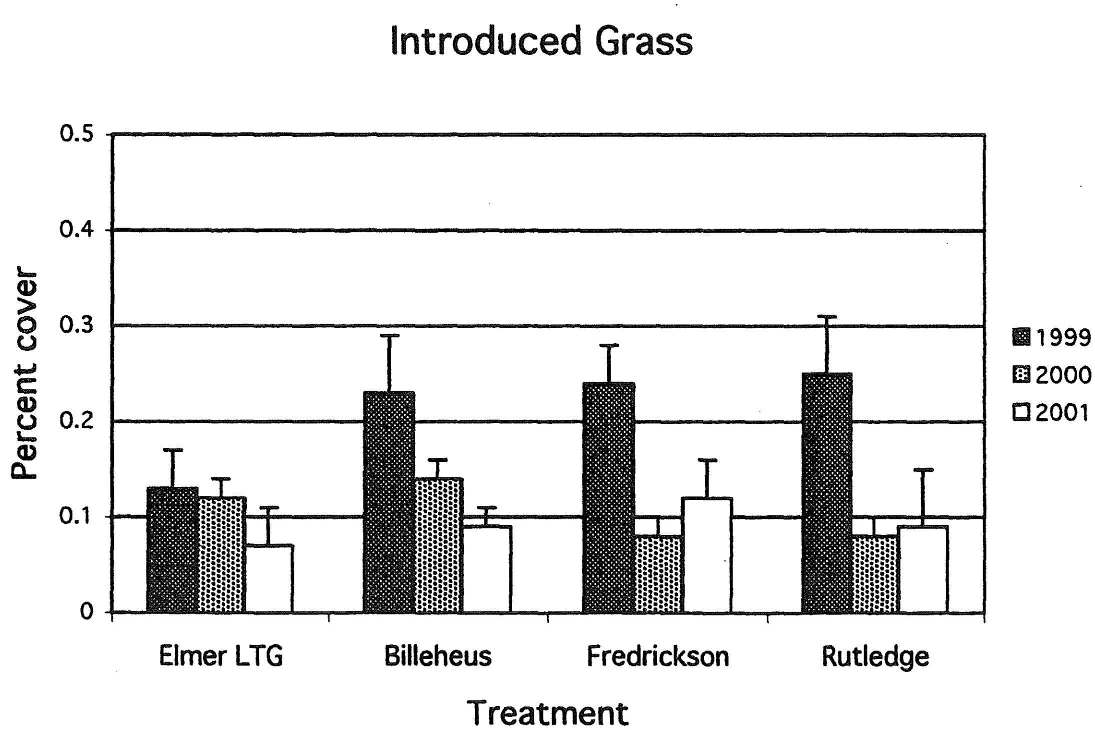

Liatris aspera
p=0.3537
(0,0)
p=0.0640
(0,1)
p=0.0620
(0,0)
p=0.0462
(0,1)
p=0.1136
(0,0)
p=0.5000
(0,0)
Liatris punctata
p=0.3644
(-1,1)
p=0.0789
(0,1)
p=0.0106
(-1,0)
p=0.0817
(0,1)
p=0.0107
(0,1)
p=0.4598
(0,0)
Echinacea angustifolia
p=0.029
(-2,0)
p=0.2426
(0,0)
p=0.0003
(-2,0)
p=0.4599
(0,0)
p=0.0017
(0,2)
p=0.2500
(0,0)
Solidago canadensis
p=0.0055
(1,6)
p=0.2055
(-2,4)
p=0.2128
(-1,5)
p=0.2027
(-3,4)
p=0.2799
(-5,1)
p=0.4452
(-3,3)
E
F
B
R

Figure 6. Among farm comparison of percent basal cover of vegetation classes over time. Basal cover was assessed using a 10-point frame (n = 300 pts./plot). Mean percent cover +/- 2 S.E. is shown. At the Elmer farm, only the data for long-term grazed (LTG) plots are shown. Management at the Elmer and Rutledge farms remained unchanged over the three-year period. Two- and three-paddock systems were instituted at the Billehus and Frederickson farms after the 1999 growing season. The first set of bars, designated LTG, refers to plots that had been grazed over the long term and that continued to be grazed throughout the experiment. The second set of bars, also designated as LTG, refers to plots that had been grazed over the long term and were grazed in 1999 but were released from grazing in 2000-2001 by the establishment of exclosures. Similarly, the third and fourth sets of bars, designated as LTU, had not been grazed for at least ten year prior to the beginning of the study. The plots represented by the third set of bars remained under the same management throughout the experiment. The plots represented by the fourth set of bars remained under the same management during 1999-2000 but were burned in early June 2001. Error bars represent +/- 2 S.E. When error bars do not overlap, frequencies are significantly different.


Bare Ground / Rock
0.6
0.5
0.4
0.3
0.2
0.1
0
Percent Cover
1999
2000
2001
Elmer LTG
Billeheus
Fredrickson
Rutledge
Treatment


Litter
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Percent cover
1999
2000
2001
Elmer LTG
Billeheus
Fredrickson
Rutledge
Treatment


Native Grass
0.5
0.4
0.3
0.2
0.1
0
Percent cover
1999
2000
2001
Elmer LTG
Billeheus
Fredrickson
Rutledge
Treatment


Introduced Grass
0.5
0.4
0.3
0.2
0.1
0
Percent cover
1999
2000
2001
Elmer LTG
Billeheus
Fredrickson
Rutledge
Treatment

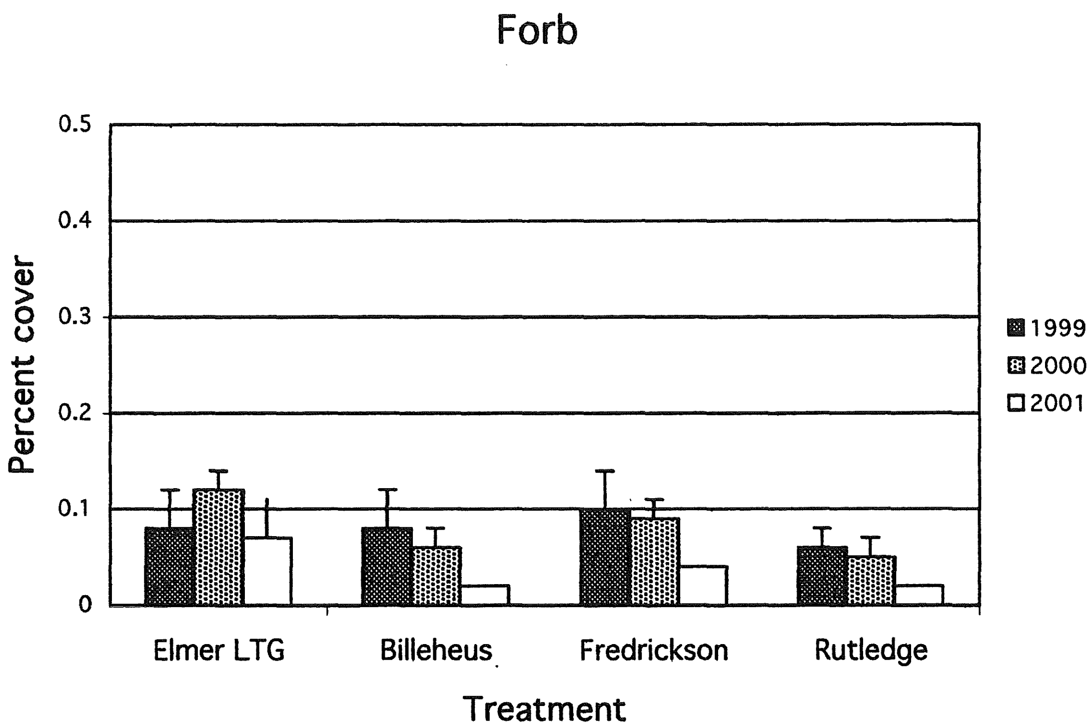
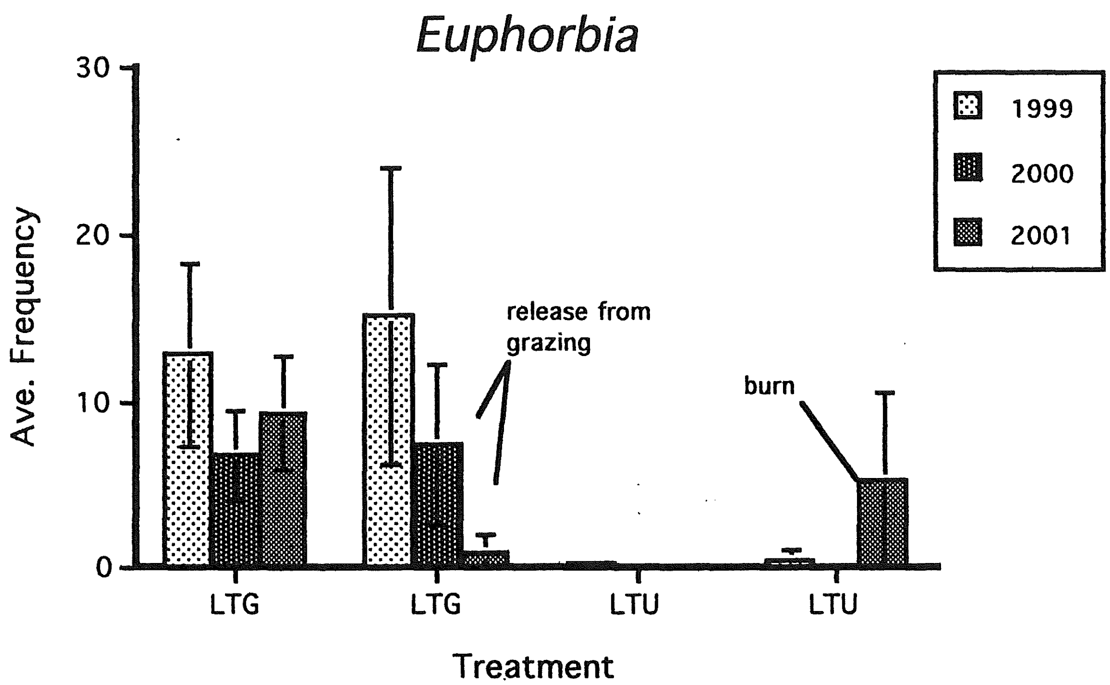

Forb
Percent cover
0.5
0.4
0.3
0.2
0.1
0
Elmer LTG
Billeheus
Fredrickson
Rutledge
Treatment
1999
2000
2001

Figure 7. Mean frequencies of ruderal species over time in experimental treatments at the Elmer farm. Applications of treatments are noted on the graph by the presence of arrows. The first set of bars, designated LTG, refers to plots that had been grazed over the long term and that continued to be grazed throughout the experiment. The second set of bars, also designated as LTG, refers to plots that had been grazed over the long term and were grazed in 1999 but were released from grazing in 2000-2001 by the establishment of exclosures. Similarly, the third and fourth sets of bars, designated as LTU, had not been grazed for at least ten year prior to the beginning of the study. The plots represented by the third set of bars remained under the same management throughout the experiment. The plots represented by the fourth set of bars remained under the same management during 1999-2000 but were burned in early June 2001. Error bars represent +/- 2 S.E. When error bars do not overlap, frequencies are significantly different.


Euphorbia
30
20
10
0
Ave. Frequency
1999
2000
2001
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment

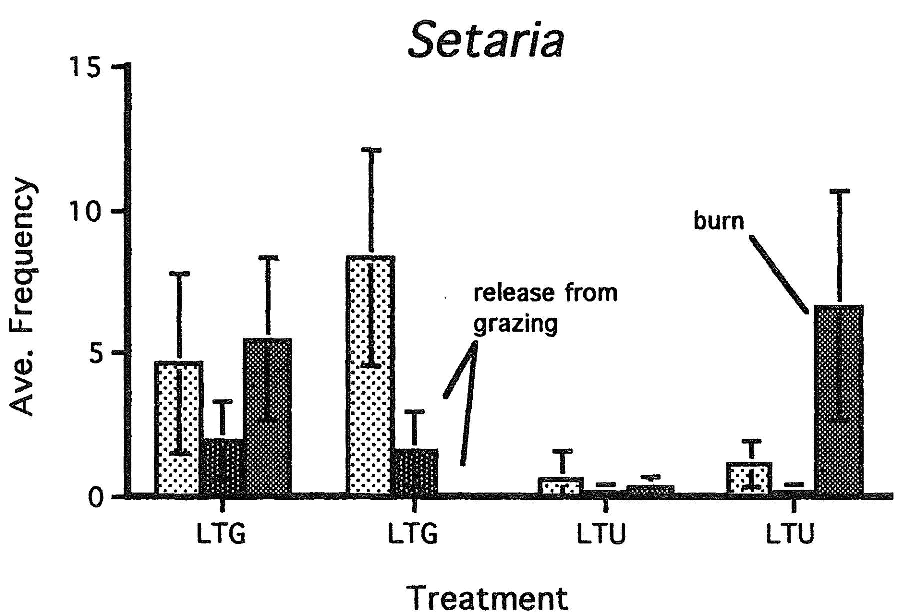
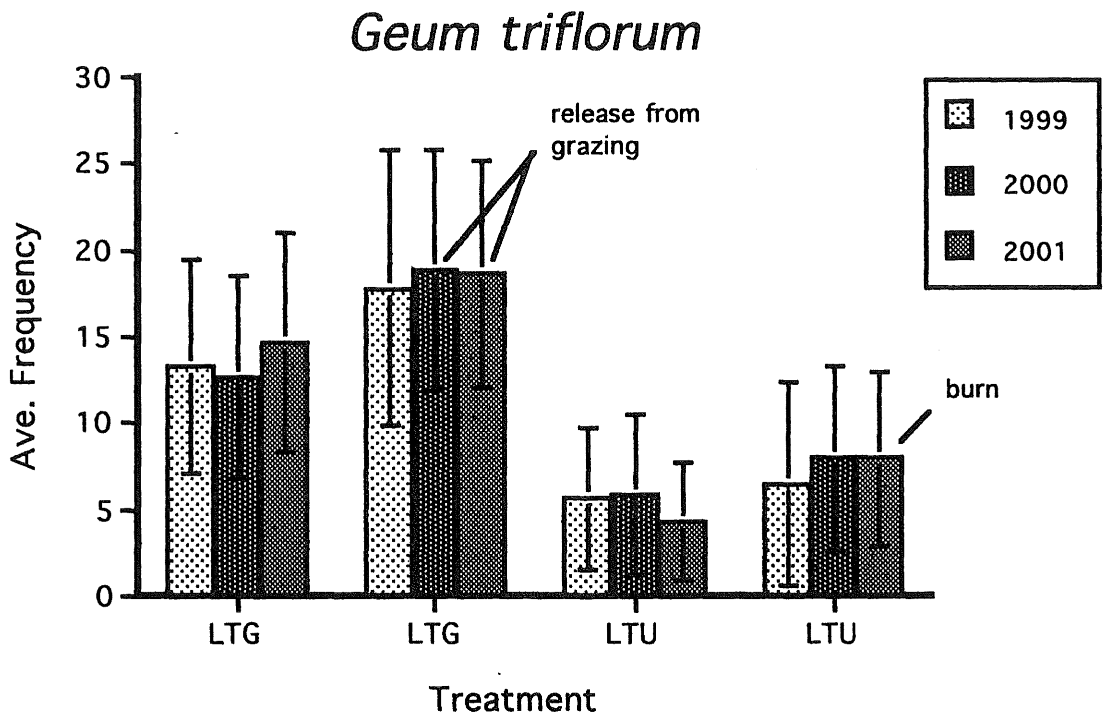

Setaria
15
10
5
0
Ave. Frequency
burn
release from grazing
LTG
LTG
LTU
LTU
Treatment

Figure 8. Mean frequencies of rosette-forming native forbs over time in experimental treatments at the Elmer farm. See the caption of Fig. 7 for an explanation of how to interpret the figure.


Geum triflorum
30
25
20
15
10
5
0
Ave. Frequency
release from grazing
1999
2000
2001
burn
LTG
LTG
LTU
LTU
Treatment

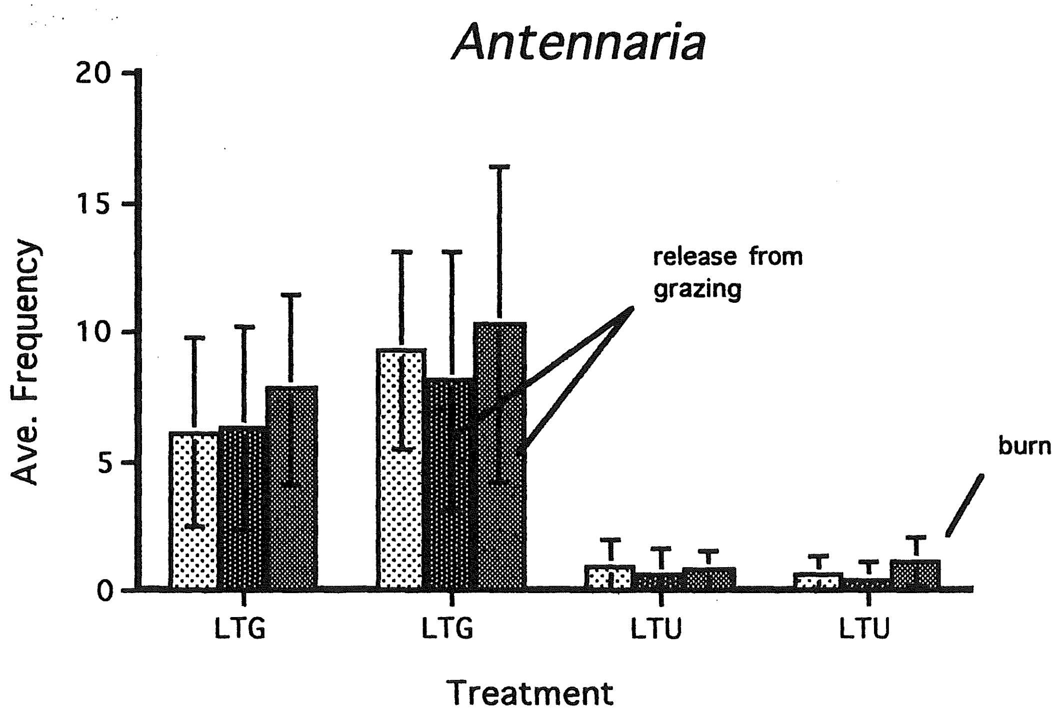
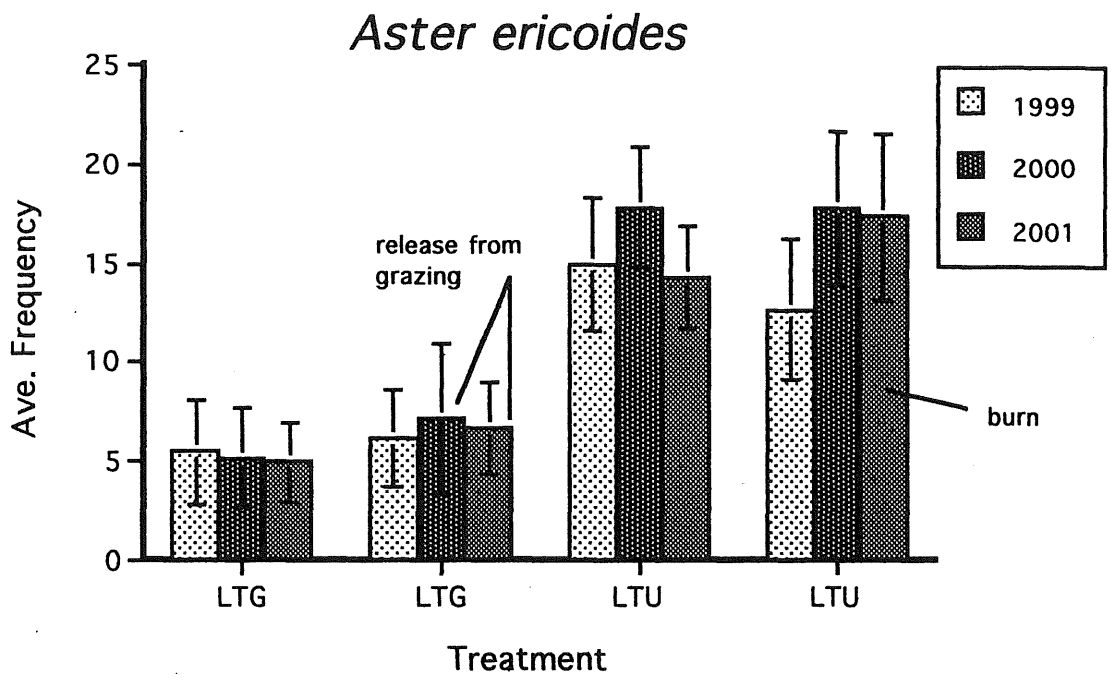
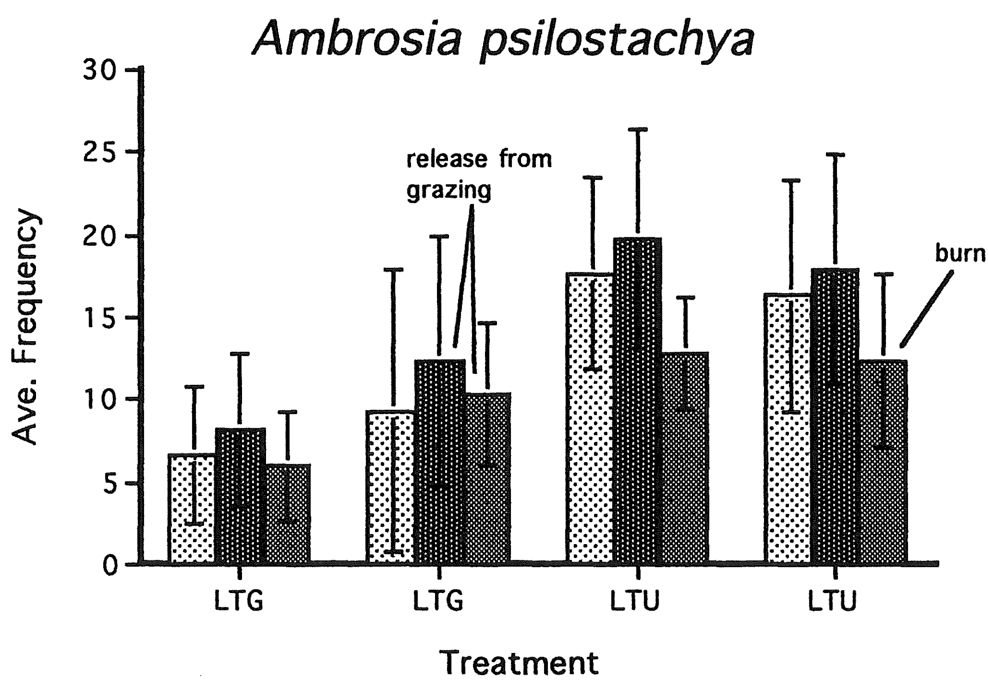
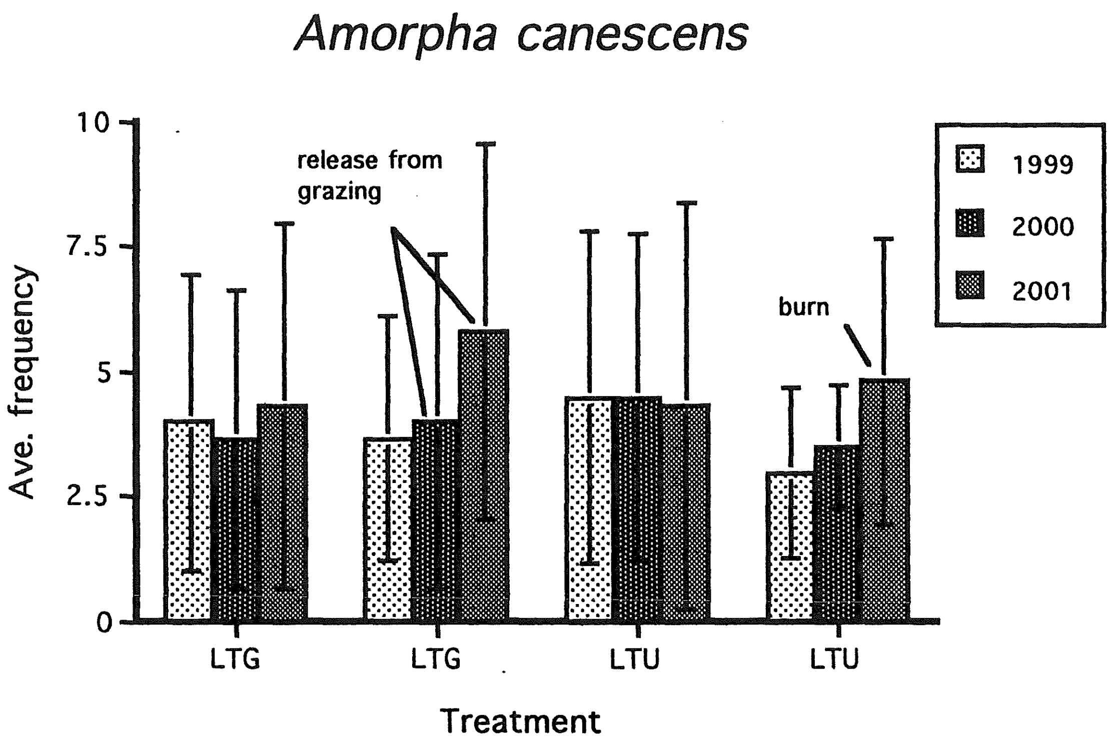
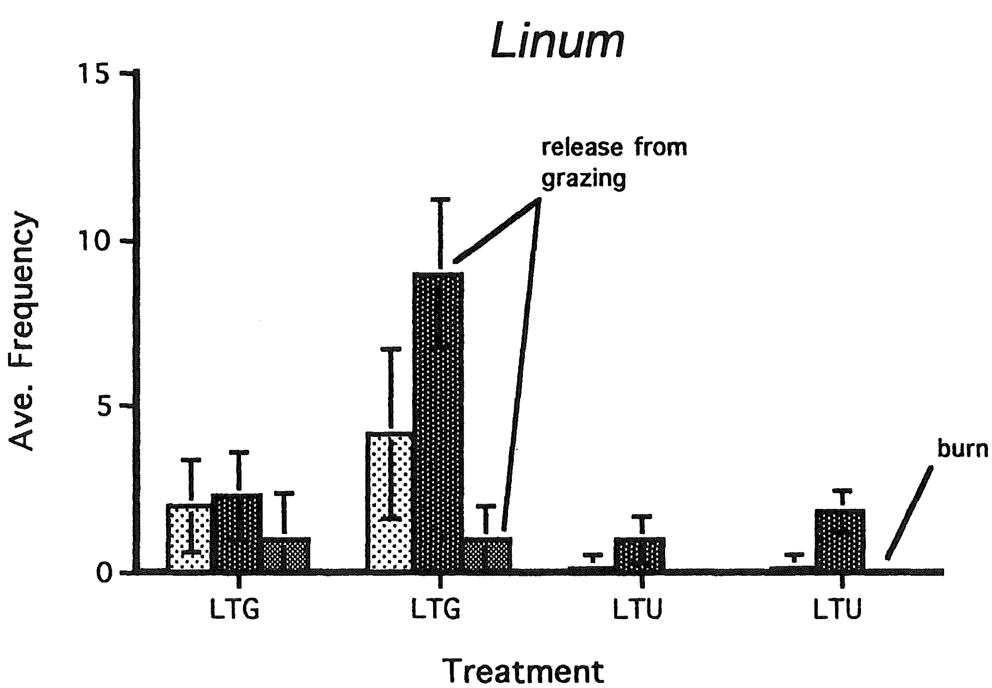

Antennaria
20
15
10
5
0
Ave. Frequency
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment

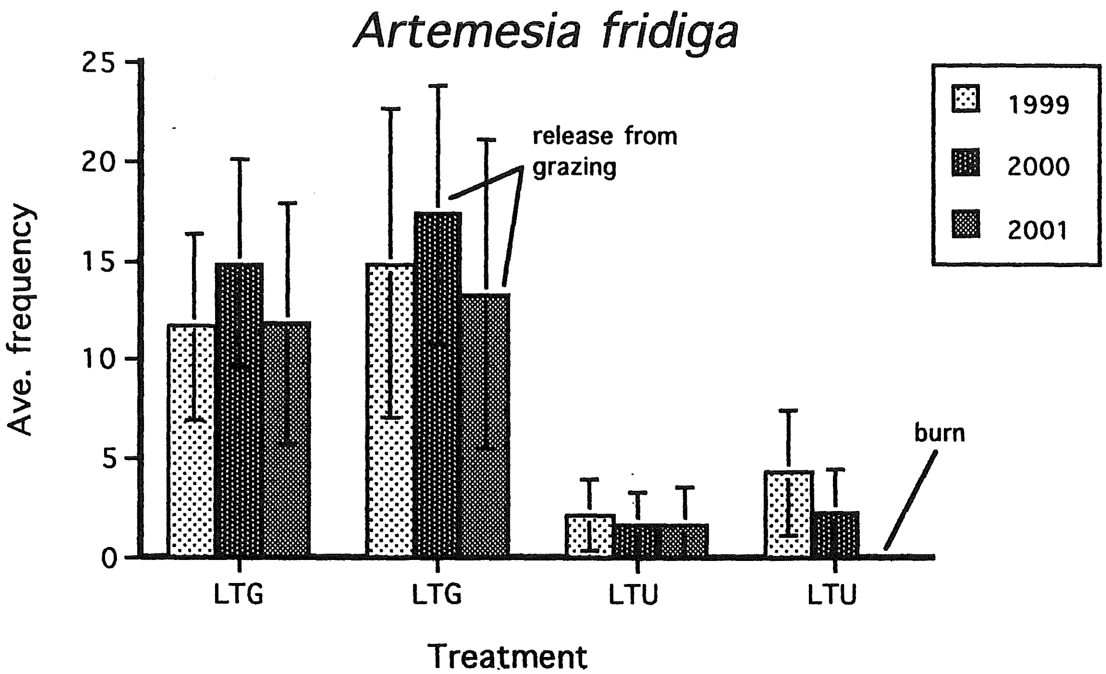
Figure 9. Mean frequencies of other native forbs over time in experimental treatments at the Elmer farm. See the caption of Fig. 7 for an explanation of how to interpret the figure.


Aster ericoides
Ave. Frequency
0
5
10
15
20
25
release from grazing
burn
1999
2000
2001
LTG
LTG
LTU
LTU
Treatment


Ambrosia psilostachya
Ave. Frequency
0
5
10
15
20
25
30
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment


Amorpha canescens
10
7.5
5
2.5
0
Ave. frequency
release from grazing
burn
1999
2000
2001
LTG
LTG
LTU
LTU
Treatment


Linum
15
10
5
0
Ave. Frequency
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment


Artemesia fridiga
25
20
15
10
5
0
Ave. frequency
1999
2000
2001
release from
grazing
burn
LTG
LTG
LTU
LTU
Treatment

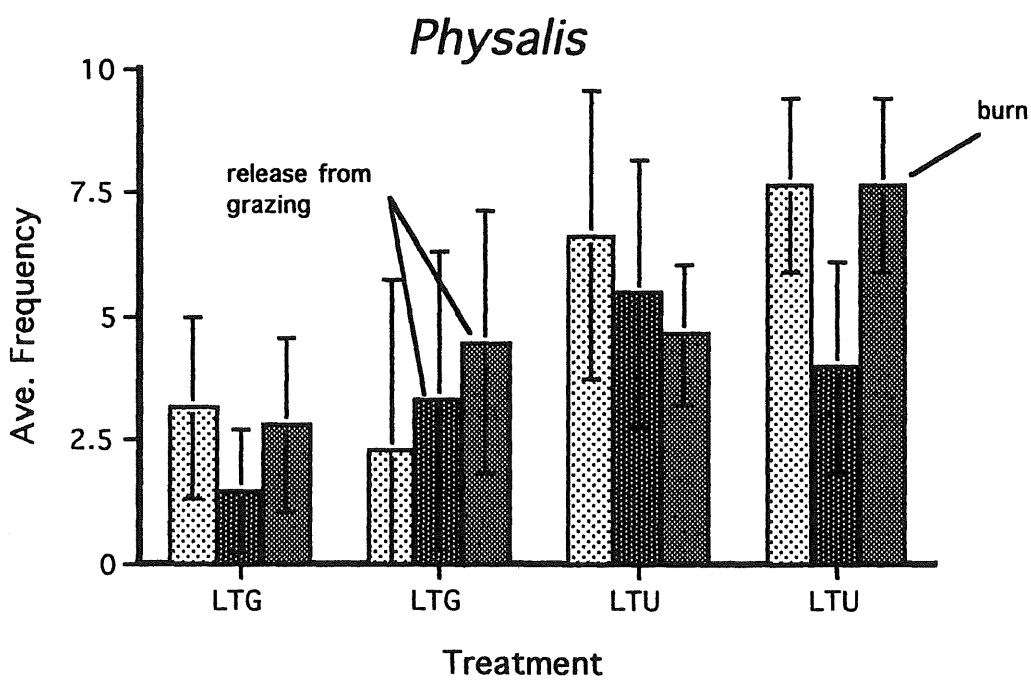
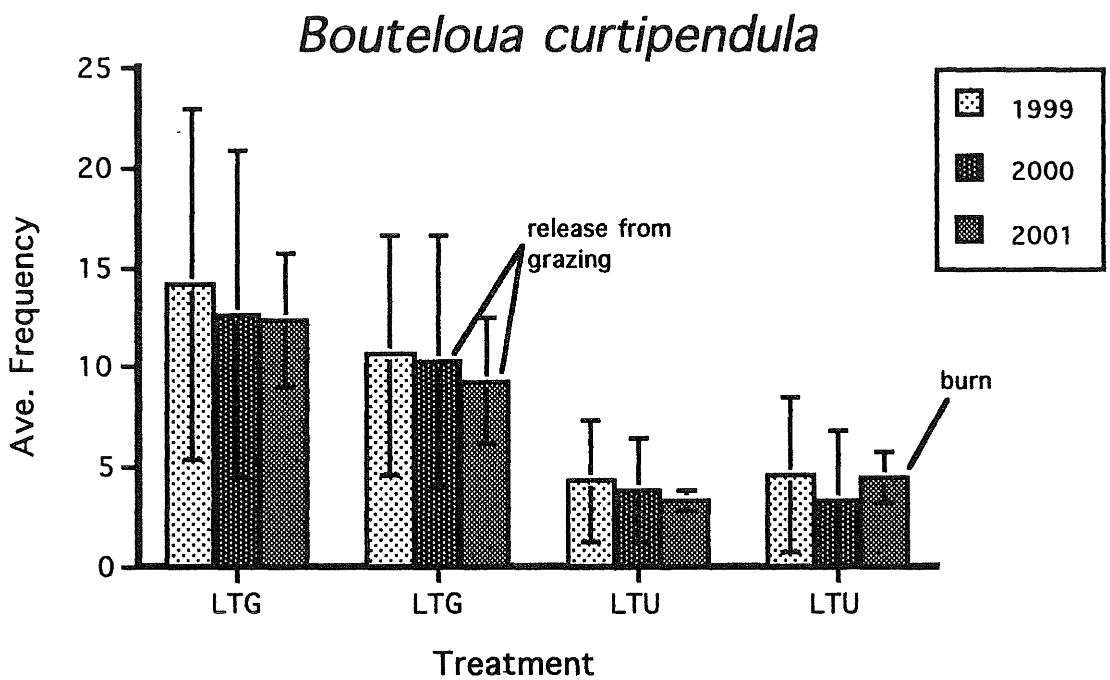
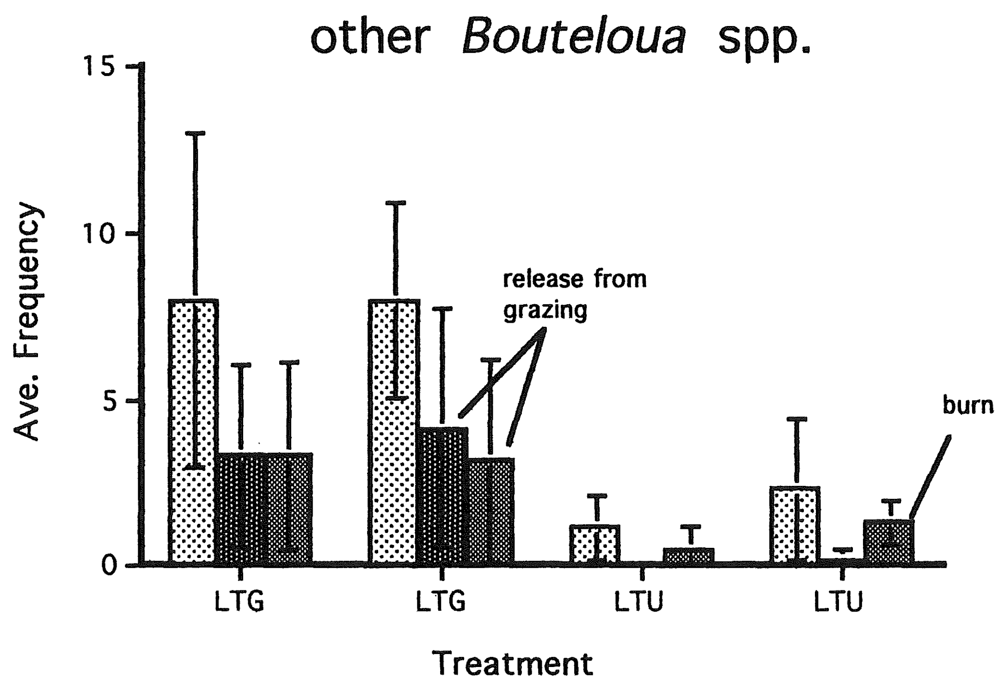

Physalis
10
7.5
5
2.5
0
Ave. Frequency
release from
grazing
burn
LTG
LTG
LTU
LTU
Treatment

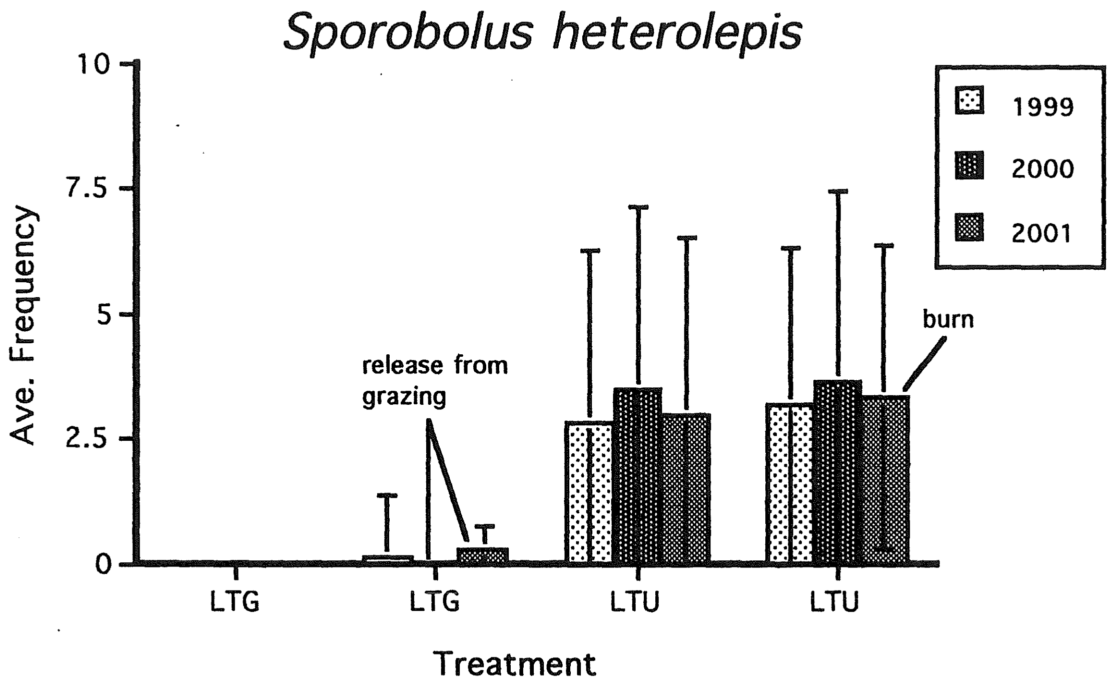
Figure 10. Mean frequencies of native grasses over time in experimental treatments at the Elmer farm. See the caption of Fig. 7 for an explanation of how to interpret the figure.



Bouteloua curtipendula
Ave. Frequency
0
5
10
15
20
25
1999
2000
2001
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment



other Bouteloua spp.
Ave. Frequency
0
5
10
15
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment


Sporobolus heterolepis
10
7.5
5
2.5
0
Ave. Frequency
1999
2000
2001
release from
grazing
burn
LTG
LTG
LTU
LTU
Treatment

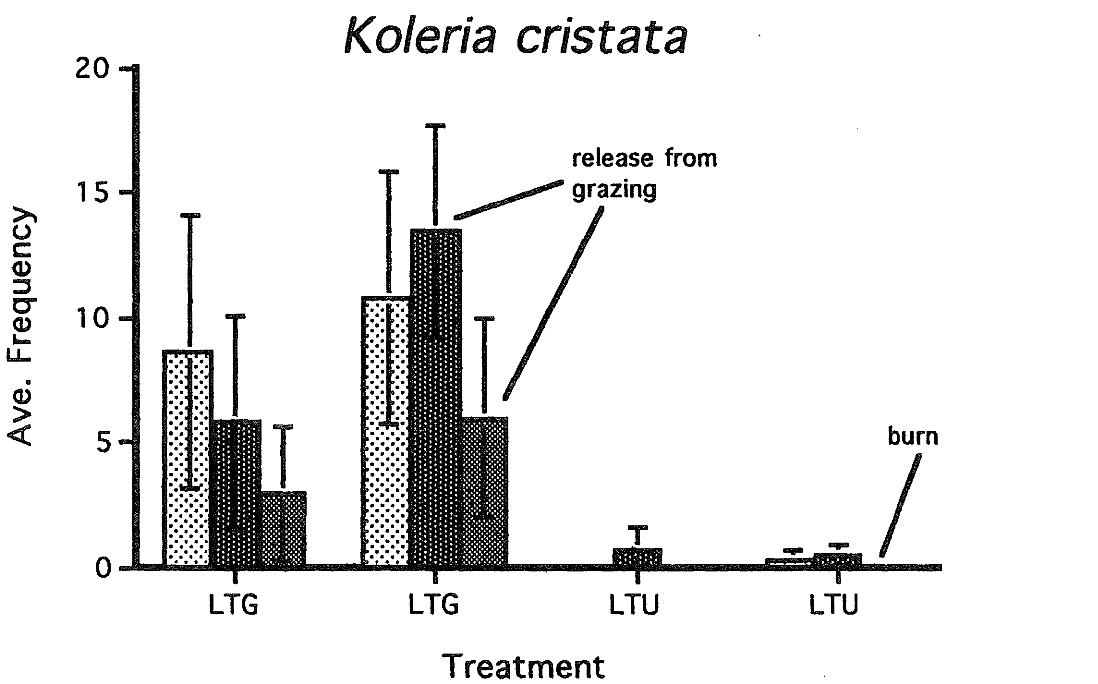
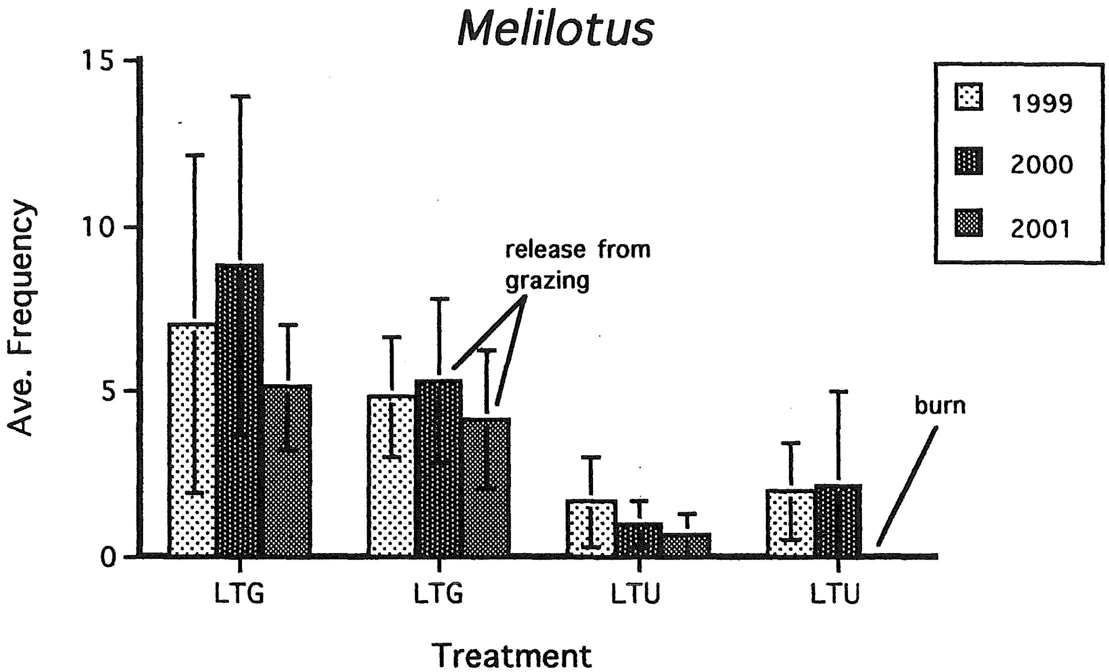

Koleria cristata
20
15
10
5
0
Ave. Frequency
release from
grazing
burn
LTG
LTG
LTU
LTU
Treatment

Figure 11. Mean frequencies of other non-native species over time in experimental treatments at the Elmer farm. See the caption of Fig. 7 for an explanation of how to interpret the figure.


Melilotus
15
10
5
0
Ave. Frequency
1999
2000
2001
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment

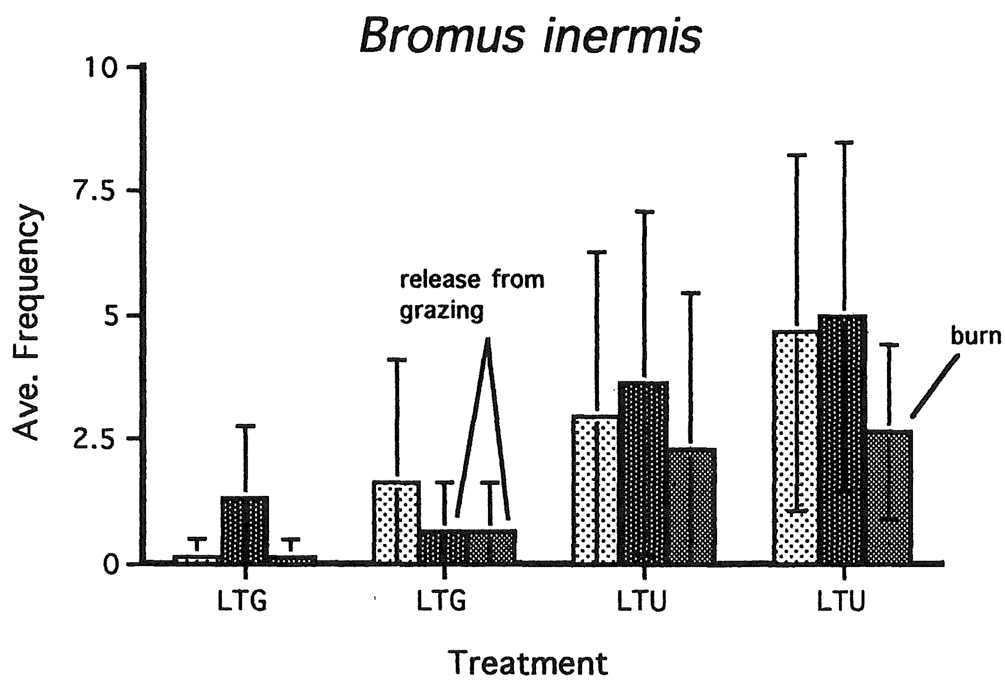
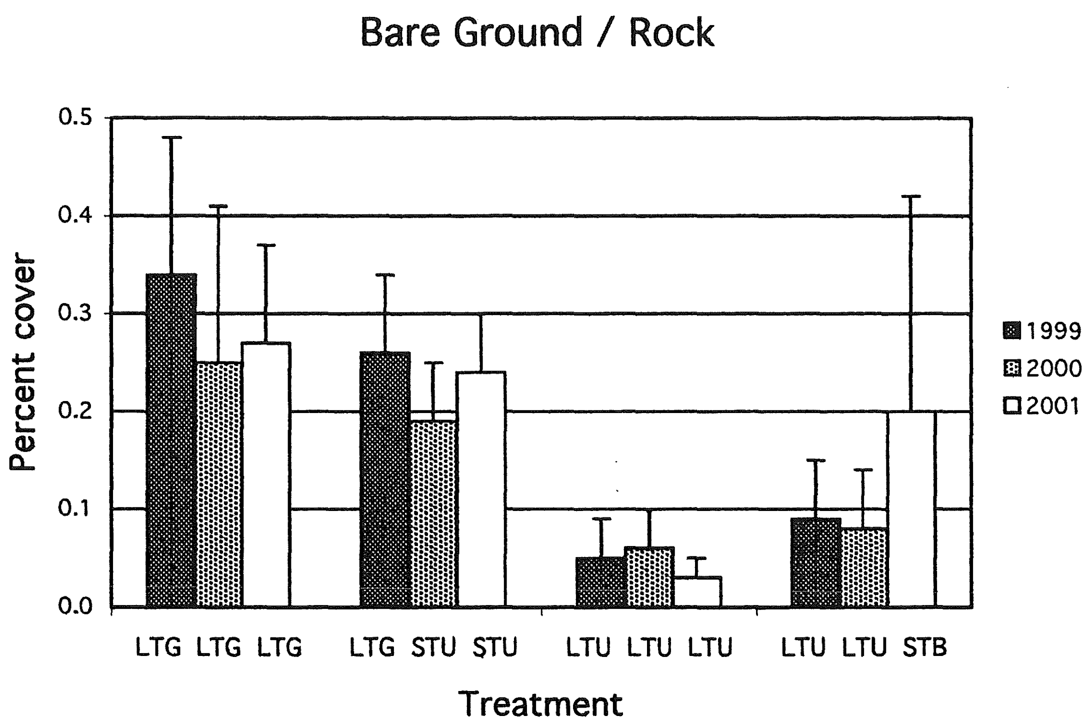
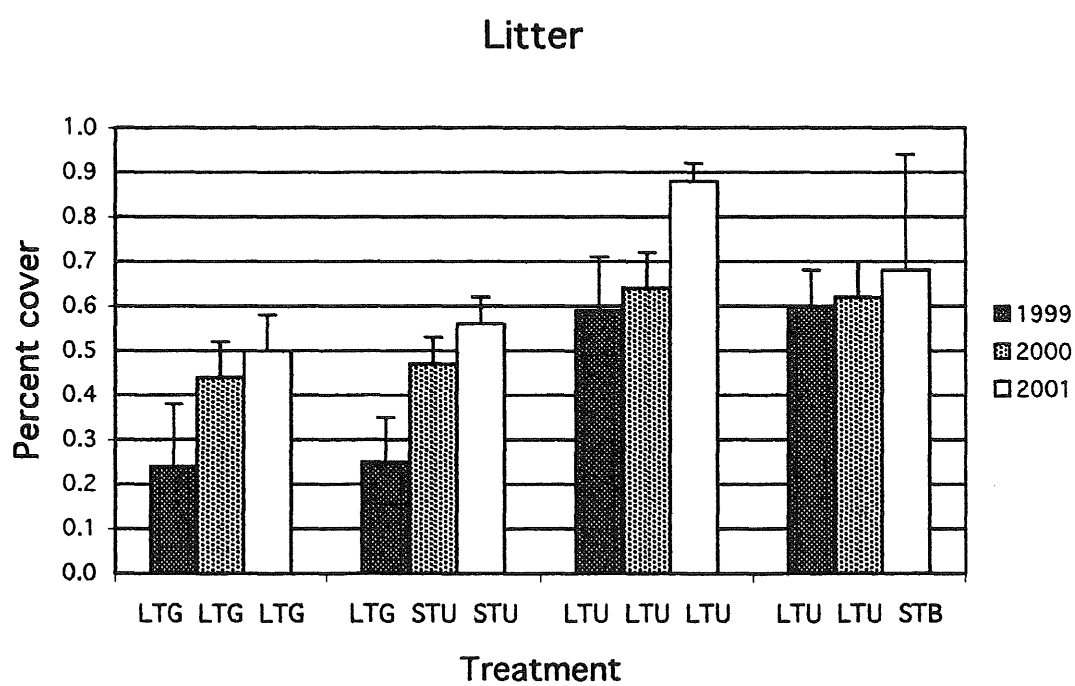
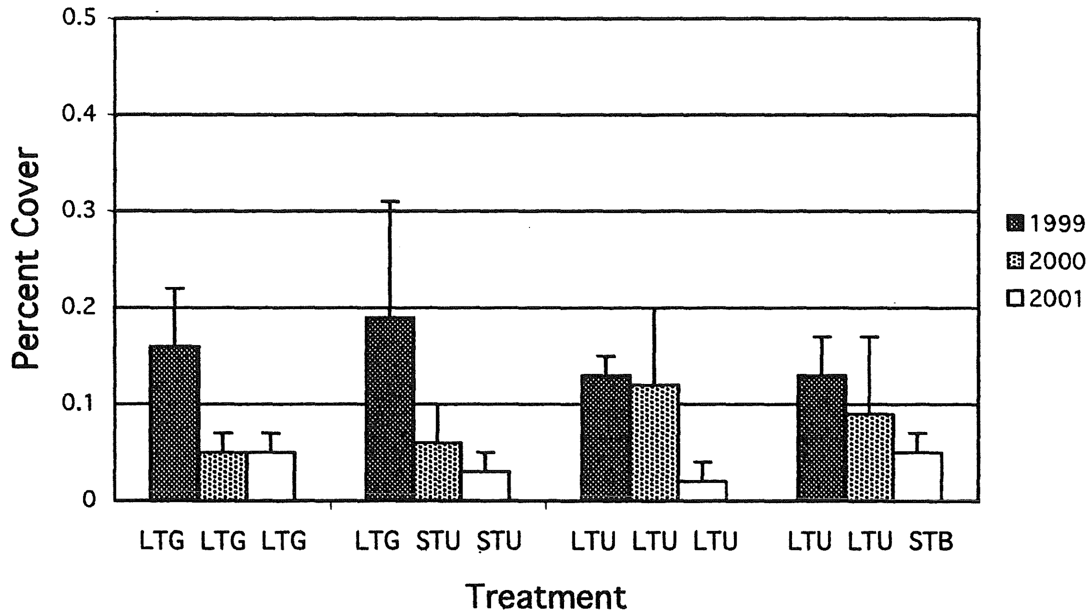

Bromus inermis
10
7.5
5
2.5
0
Ave. Frequency
release from grazing
burn
LTG
LTG
LTU
LTU
Treatment

Figure 12. Among treatment comparison of percent basal cover of vegetation classes over time. Basal cover was assessed using a 10-point frame (n = 300 pts./plot). Mean percent cover +/- 2 S.E. is shown. The first set of bars refers to plots that had been grazed over the long term (long-term grazed = LTG) and that continued to be grazed throughout the experiment. The second set of bars refers to plots that had been grazed over the long term, and grazed in 1999, but that were released from grazing in 2000-2001 by the establishment of exclosures (short-term ungrazed = STU). The third set of bars refers to plots that had not been grazed for at least ten years prior to the beginning of the study (long-term ungrazed = LTU) and remained grazed throughout the experiment. The fourth set of bars refers to plots that remained ungrazed (LTU) during 1999-2000 but were burned in early June 2001 (short-term burned = STB).

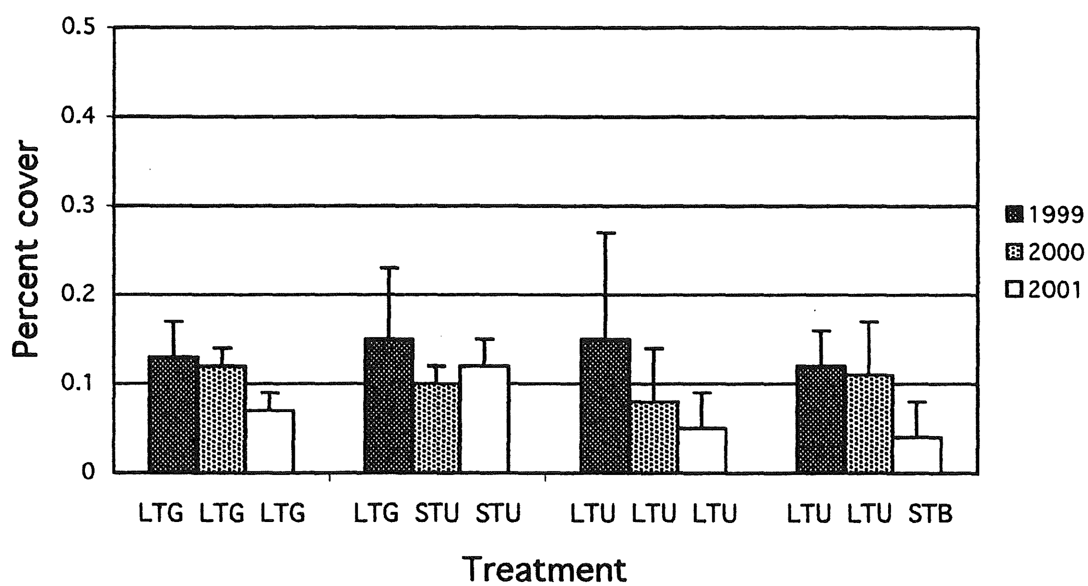

Bare Ground / Rock
0.5
0.4
0.3
0.2
0.1
0.0
Percent cover
1999
2000
2001
LTG LTG LTG
LTG STU STU
LTU LTU LTU
LTU LTU STB
Treatment


Litter
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Percent cover
1999
2000
2001
LTG LTG LTG
LTG STU STU
LTU LTU LTU
LTU LTU STB
Treatment

Native Grass



Introduced Grass



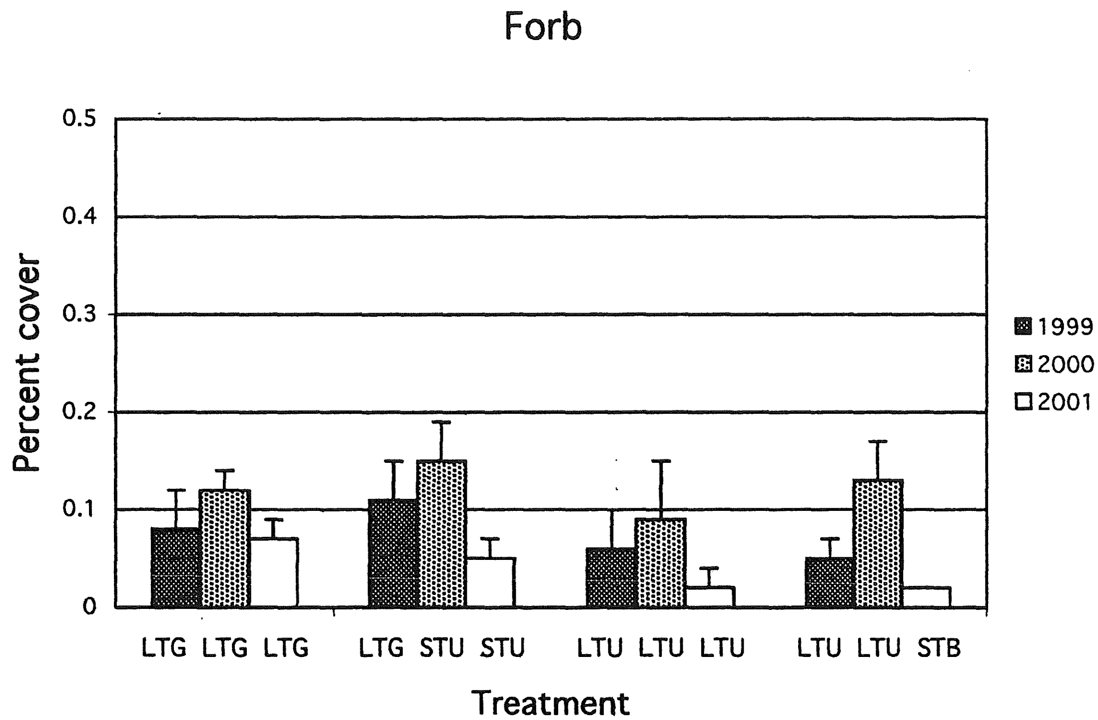
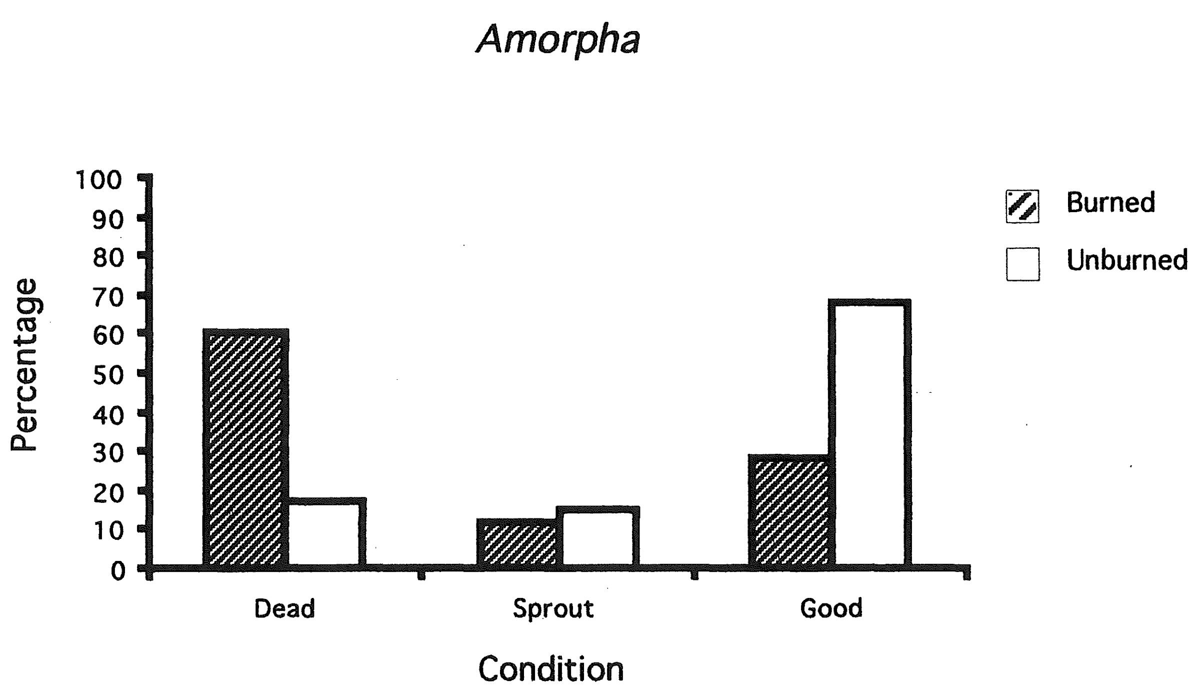

Forb
0.5
0.4
0.3
0.2
0.1
0
Percent cover
1999
2000
2001
LTG LTG LTG
LTG STU STU
LTU LTU LTU
LTU LTU STB
Treatment

Figure 13. Response of woody species to fire. In all cases there was a significant difference in condition of plants between burned and unburned plots (Cochran-Mantel-Haenszel test, $p < 0.001$). The majority of stems in unburned plots were in good condition, whereas in burned plots the majority were dead or new sprouts. a) All woody species; response of all eleven species, n = 1988 stems; b) *Amorpha canescens* (leadplant), n = 376 stems; c) *Rosa* spp. (rose), n = 249 stems; d) *Symphoricarpos occidentalis* (western snowberry), n = 1228 stems.

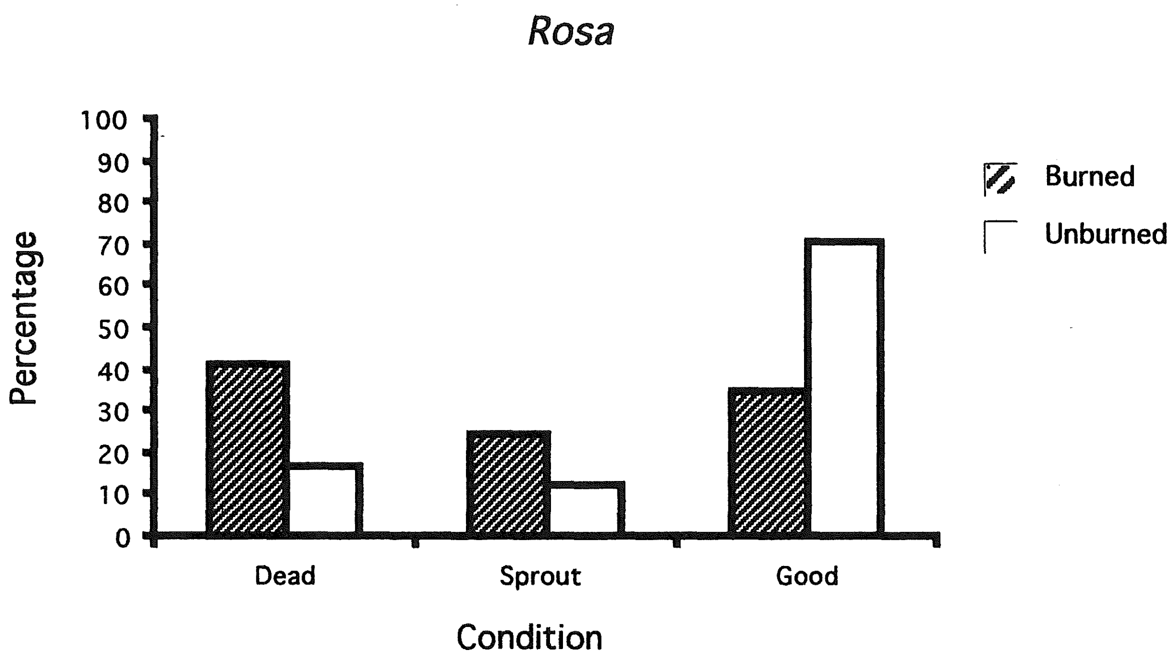
a)


All Species
Percentage
100
90
80
70
60
50
40
30
20
10
0
Dead
Sprout
Good
Condition
Burned
Unburned

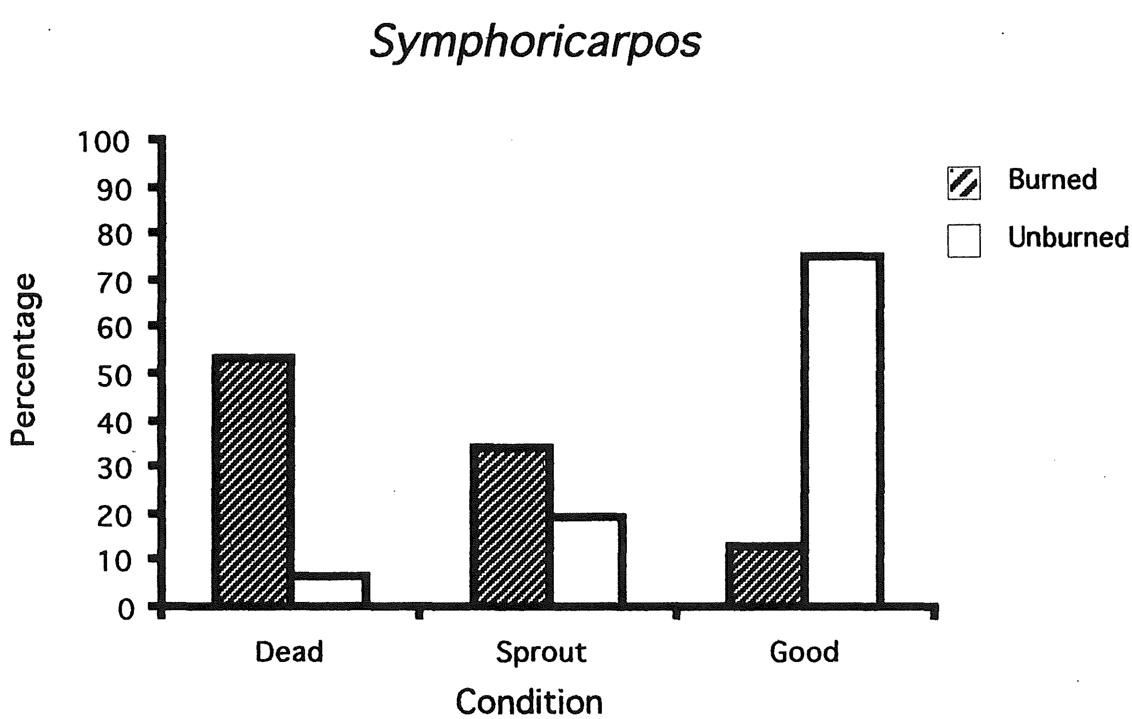
b)


Amorpha
Percentage
100
90
80
70
60
50
40
30
20
10
0
Dead
Sprout
Good
Condition
Burned
Unburned

c)


Rosa
100
90
80
70
60
50
40
30
20
10
0
Percentage
Burned
Unburned
Dead
Sprout
Good
Condition

d)


Symphoricarpos
100
90
80
70
60
50
40
30
20
10
0
Percentage
Burned
Unburned
Dead
Sprout
Good
Condition

Livestock performance and plant persistence when grazing warm-season native grasses.

Greg J. Cuomo and Av Singh. West Central Research and Outreach Center, University of Minnesota, Morris.

Funding for this study provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources (LCMR).

ABSTRACT only [a]

Native prairies provide habitat for wildlife and unique plant species as well as aesthetic beauty. Historically, native prairies also supported large herbivores. This study evaluated animal performance and stability of native grass plant communities under several grazing management strategies. Yearling dairy heifers grazed warm-season grasses at high and low stocking rates under continuous grazing or in 2, 4, 8, 16, or 32-paddock grazing systems. Native grasses were established in 1997 and included big bluestem, Indian grass, switchgrass, sideoats grama, and little bluestem. These pastures were grazed for 48 days from late-June through mid-August in 1999 and 2000. At the initiation of the study, native grass plant communities were dominated by big bluestem and Indian grass. A relatively heavy infestation of quackgrass was also present. Animal performance over the 2-year study was similar among grazing treatments and averaged 1.41, 1.42, 1.45, and 1.38 lb/d for high and low stocking rates and for continuous and rotational grazing, respectively. Species composition was similar at the beginning and end of this trial across grazing treatments. Lack of response in species composition to grazing treatment was likely the result of the short duration (2 years) of the study and that grazing was conducted from late-June through mid-August. This grazing period resulted in a relatively long rest for plants between grazing and frost and may have mitigated negative impacts of grazing treatment. Similar animal performance and short-term plant community stability demonstrated in this study may imply that when a late-summer rest period is provided before frost, management for wildlife habitat could be used as the determining factor when identifying a grazing system for native grass pastures. The native grass mixture used in this study contained few species and did not include forbs. The persistence of desirable, but minor species could also be a criteria used for selecting grazing systems in native grass pastures.

[a] Manuscripts and reports are planned for producer-oriented publications.

EFFECTS OF POST-BURN AGE AND PRAIRIE TYPE ON BREEDING BIRDS OF NORTHWEST MINNESOTA.*

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Funding for this study provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources.

Abstract:

Few studies have determined effects of prescribed burning on breeding bird populations in the tallgrass prairie of northwest Minnesota. In 1999, 27 study plots were established along the eastern beach ridges of former glacial Lake Agassiz in northwest Minnesota. Of the 27 study plots, 9 plots were located in each of the following prairie types: moist prairie, wet prairie, and brush prairie. In each prairie type, the 9 plots were equally divided within 3 post-burn ages: Year-0 (plots burned in the spring or the previous fall); Year-1 (plots with 1 full growing season); and Year-3 + (plots with at least 3 full growing seasons since the last burn). In 2000, 27 new plots were located in the same fashion. On each of the 54 study plots, data were collected on population density of breeding birds by censusing each plot twice during the breeding season. In 2000, 45 species were recorded on census plots and 41 in 1999. The 4 most common species were savannah sparrow, LeConte's sparrow, bobolink, and clay-colored sparrow. Savannah sparrows and LeConte's sparrows occurred in relatively high densities on each of the habitat types. LeConte's sparrows, however, appeared to strongly select against Year-0 burn-age plots during both 1999 and 2000. Clay-colored sparrows strongly preferred brush prairie types and appeared to select against Year-0 burn ages. Bobolinks seemed to prefer Year-1 plots in 2000, while selecting for Year-0 plots in 1999. During both years, bobolinks appeared to select against brush prairie plots.

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* A master's thesis is under preparation in the Biology Department of the University of North Dakota under the supervision of Richard Crawford and Daniel Svedarsky. Statistical analysis of data in this report is incomplete as of this writing, 30 June 2002.

EFFECTS OF POST-BURN AGE AND PRAIRIE TYPE ON BREEDING BIRDS OF NORTHWEST MINNESOTA.

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Funding for this study provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources.

INTRODUCTION:

The tallgrass prairie has become one of the most imperiled ecosystems in North America. It is estimated that Minnesota has only about 0.5 % of its original acreage remaining. While many prairies are under public ownership, substantial areas are privately owned. Recent research indicates that grassland nesting birds have a higher proportion of declining species that any other avian guild in North America (Steinauer and Collins 1996). The management of remaining prairies for the conservation of grassland-dependent flora and fauna becomes even more critical.

Prairie species historically evolved with the interaction of disturbances such as fire, grazing, flooding, and drought. If these disturbances were to be taken out of the prairie, it would change the ecosystem significantly. Studies have shown that grassland areas spared from some sort of disturbance regime have both less avian diversity and fewer individual birds (Herkert, Sample, and Warner 1995). A disturbance regime is especially important on the eastern edge of the tallgrass prairie where there is adequate precipitation to support woody plants. Agencies often use prescribed burning as part of a disturbance regime to manage remnant prairies.

Few studies have evaluated effects of management practices, such as fire, on grassland bird species in northern tallgrass prairie of western Minnesota. Most studies have been performed in southern portions of the tallgrass prairie or in the mixed-grass prairie farther west where there are significant differences in climate and vegetation.

OBJECTIVES:

To evaluate effects of post-burn age on the occurrence and abundance of breeding prairie birds in mesic, wet, and brush prairie habitat types.

STUDY AREA:

During both the 1999 and 2000 field seasons, 27 study plots were located along the eastern beach ridges of former glacial Lake Agassiz in northwest Minnesota (54 plots total). The study area included the following counties: Polk, Norman, Mahnomen, Clay, Wilkin, and Otter Tail. Plots of 3 to 16 hectares were distributed throughout the study area to reduce effects of latitude. Study sites included lands owned by the Minnesota Department of Natural Resources, The Nature Conservancy, and private landowners.

METHODS:

A two-way factorial experimental design was implemented to evaluate the following questions: (1) Does post-burn age affect species richness and density? (2) Does the habitat type being burned affect the species richness and density? (3) Are there interactive effects between post-burn age and habitat type? All study plots were located on native or restored prairie with similar vegetation structure and composition within each of the 3 habitat types. The main effects of this design were habitat type and post-burn age, with replicate plots within each habitat type/post-burn age combination.

Vegetation characteristics and bird abundance were measured on all 54 plots. Breeding bird richness and density were determined by the strip transect census (Stewart and Kantrud 1972). Transects were marked as a grid with wooden lathes at 50-m intervals along the center of the transect and at 50 m on both sides. Surveys were conducted twice on each plot during the breeding season. Censuses were performed from late-May through June during peak activity between sunrise and 1000 hr. Censuses were not conducted during times when excessive precipitation or wind created bias (Mikol 1980). The maximum count of males was used to determine density for each species (number of males/ 100 ha).

Vegetation was systematically assessed at 25 to 50 measuring points located throughout plots. The number of points taken was directly related to the length of the transect. Vegetation was measured once from early to mid-July. Measurements included vegetation height, litter depth, percent cover by growth form (graminoid, forb, woody, bare ground, litter, and standing residual) using a 20x50-cm Daubenmire frame (Daubenmire 1959), visual obstruction reading (VOR) using a Robel pole (Robel et al. 1970), and number of small ($\leq$30 cm) and large (>30 cm) woody stems.

RESULTS:

1999. Savannah sparrows were the most common bird on census plots and were present on all but 2 plots (93%). While numbers tended to be highest in moist prairie and the 3+ burn category, there were no significant associations. Clay-colored sparrows were the second most common species; counted on all but 3 plots (89%). The number of birds found on brush prairie was significantly higher than other prairie types (p = 0.000). Clay-colored sparrows also tended to select against the Year-0 burn category. Sedge wrens were absent on 9 plots including 8 out of 9 in the Year-0 burn category (67%) and strongly selected against the Year-0 burn category and mesic prairie (p = 0.001 and p = 0.040, respectively). LeConte's sparrows were absent on 10 plots, including 8 out of 9, Year-0 plots (63%) and selected against the Year-0 burn category (p = 0.000). Bobolinks were absent on 12 of the 27 plots, including all 9 brush plots (56%). They strongly selected against brush prairie (p = 0.001) and for Year-0 plots (p = 0.040).

2000. Savannah sparrows were found on all but 4 plots (85%) and preferred wet prairie (p = 0.025). LeConte's sparrows were absent on 9 plots including 8 of 9, Year-0 plots (67%). They selected against the Year-0 burn category (p = 0.006). Clay-colored sparrows were absent on 13 plots (52%) and found on only 1 of 12, Year-0 plots in the wet and mesic prairie. They selected for brush prairie (p = 0.000). Bobolinks were absent on 13 plots (52%), including 8 of 9, Year-0 plots and appeared to select against brush plots and Year-0 burn category. Sedge wrens were recorded on 44% of plots.

In 2000, 45 species of birds were recorded compared to 41 in 1999. The 4 most common species were savannah sparrow, Le Conte's sparrow, bobolink, and clay-colored sparrow. Savannah sparrows and Le Conte's sparrows occurred in relatively high densities on each of the habitat types. LeConte's sparrows, however, appeared to strongly select against Year-0 burn-age plots during both 1999 and 2000. Clay-colored sparrows strongly preferred brush prairie types and appeared to select against Year-0 burn ages. Bobolinks seemed to prefer Year-1 plots in 2000, while selecting for Year-0 plots in 1999. During both years, bobolinks appeared to select against brush prairie plots.

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EFFECTS OF GRAZING INTENSITY AND PRAIRIE TYPE ON BREEDING BIRDS IN NORTHWEST MINNESOTA*

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Funding for this study provided by the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources.

Abstract:

Effects of grazing on breeding birds of tallgrass prairie have not been systematically evaluated in northwest Minnesota. In this 2-year study, birds were censused in wet, mesic, dry, and brush prairie types under 3 intensities of grazing; light, moderate, and heavy as indicated by litter depth. A total of 18 bird species were censused during 2000 and 2001 in 72 plots. Savanna sparrows were the most abundant and were found in all combinations of prairie type and grazing intensity. They were followed in abundance by grasshopper sparrows, clay-colored sparrows and bobolinks. In all prairie types, moderately-grazed plots contained more breeding bird than in light and heavy graze categories, suggesting positive values of grazing as a prairie management tool.

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* Data in this report have been summarized but statistical analysis is incomplete as of this writing, 30 June 2002.

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INTRODUCTION:

In the United States, approximately 30% of the total land area is native rangeland or permanent pasture. Most of this lies in the grassland biome of central North America and, in the eastern area, agricultural and other developments have fragmented the tallgrass prairie portion. Tallgrass prairie was historically dominated by big bluestem (*Andropogon gerardii*), little bluestem (*Schizachryrium scoparium*), Indian grass (*Sorghastrum nutans*) and switchgrass (*Panicum virgatum*). The prairie developed under the influence of floods, drought, fire, and grazing. Climatic factors like flooding and drought are random and can be difficult to manage, if not impossible. However, fire and grazing can be managed. Considerable public land in the tallgrass prairie region is burned to stimulate growth, reduce litter depth, and control woody plant encroachment. Fire is used effectively by many land managers as a tool to manage habitat but is costly, involves man-hours, and is restricted by season and climate. Grazing has fewer weather or climate restrictions than fire may be a desirable management alternative.

It seems logical to assume that moderate grazing could enhance biodiversity, habitat utilization, and help maintain ecosystem health since it was a natural ecosystem disturbance. Biomass consumed by grazing is utilized more efficiently by not hindering the following year's growth with litter accumulation and excess residual cover. This can result in higher productivity of plants the following year. Furthermore, consumption of this forage by grazers, verses decomposition and decay, moves energy through trophic levels more effectively. Grazing also provides a source of economic return to private landowners who hold title to over 75 % of the remnant prairie in Minnesota.

Herkert et al. (1995) indicated that grassland areas without disturbance have less bird diversity and fewer individuals than those that do. How does disturbance, grazing in this case, affect use by breeding birds in the tallgrass prairie of Minnesota? This information can lead to management recommendations for privately-owned prairies as well as evaluating the possible use of grazing as a management tool for prairies under public ownership. This study aimed to measure relationships between grazing intensity, prairie type, and breeding birds in remnant tallgrass prairies in northwest Minnesota during the field seasons of 2000 and 2001. Experimental design was a 2-way factorial design to address the following questions:

- Does the prairie type being grazed affect breeding bird abundance and species richness?
- Does the grazing intensity affect breeding bird abundance and species richness?
- Are there interacting effects between prairie type and grazing intensity?
- What are management alternatives for breeding grassland birds as a result of these factors?

Table 1. Matrix of proposed study plan.

Grazing intensity	Prairie Type			
	Dry	Mesic	Wet	Brush prairie
Light	3*	3	3	3
Moderate	3	3	3	3
Heavy	3	3	3	3

** Number of plots per category for each year of the study.*

STUDY AREA:

A total of 72 plots were established for the study. Plots were located in Polk, Red Lake, Norman, and Clay counties within the beach ridge complex of former Lake Agassiz in northwestern Minnesota's tallgrass prairie region (Figure 1). Landowners were asked to participate by permitting the study to be conducted on their land. Efforts were made

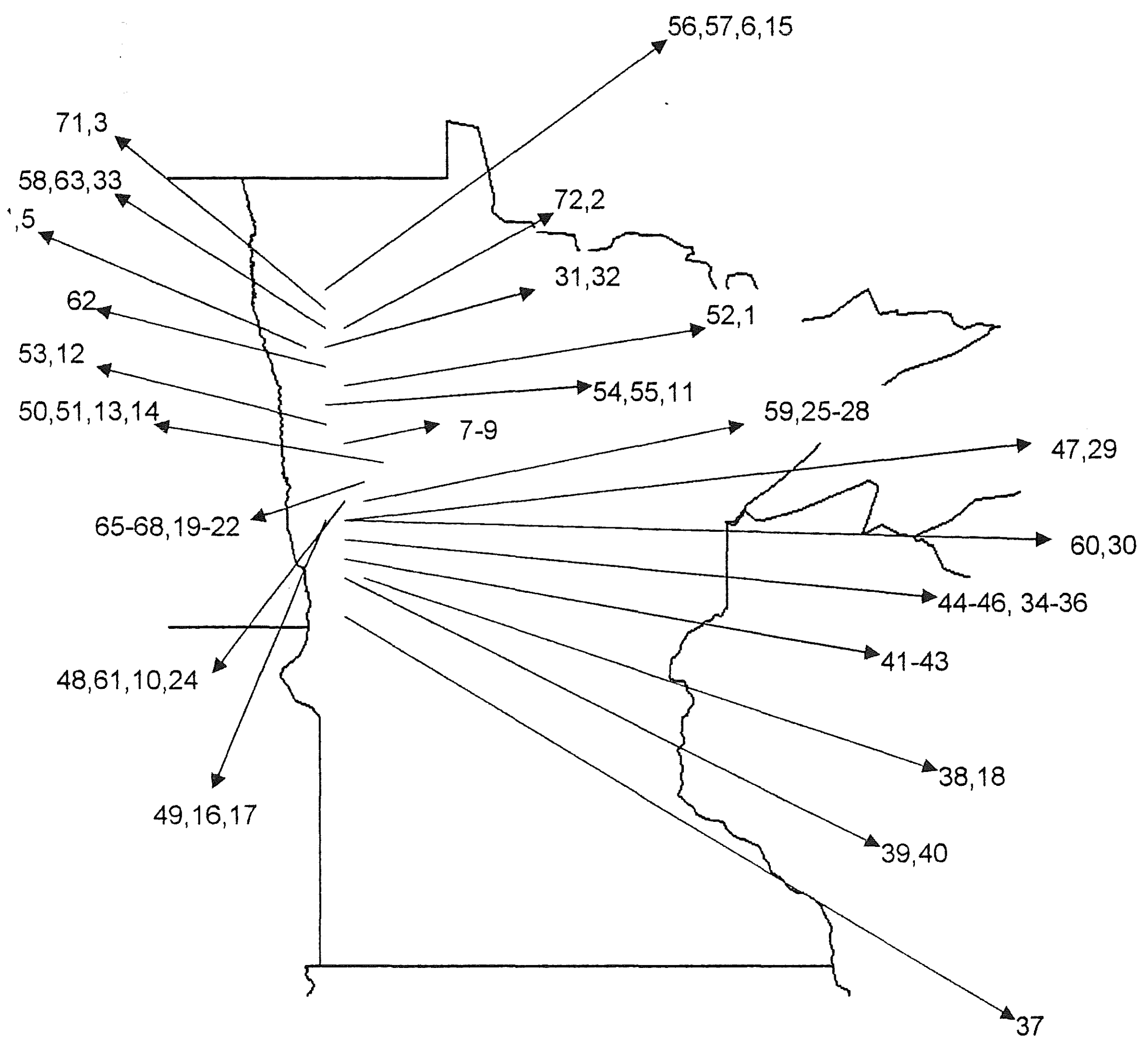


Figure 1. Owner and location of grazed plots for breeding bird survey.

to ensure that each transect was located on a native prairie remnant. Of the 72 sites, 69 plots were native prairie remnants that had never been tilled. The remaining 3 sites (plots 39, 40, and 62) were in permanent pasture and had not been plowed or altered in at least 40 years.

METHODS:

Grazing intensity. It can be difficult to define what constitutes light, moderate, and heavy grazing for various range types (Weins and Dyer 1975) and how it affects breeding bird habitat. Does one determine grazing intensity on a yearlong basis, or only during the nesting period? We assumed bird use was mainly dependent on conditions during the nesting season so grazing intensity was determined at the time of bird counts. The Robel pole (Robel et al. 1970) was used to measure litter depth and visual obstruction readings (VOR) as indicators of light, moderate, and heavy grazing. Litter depth was used as the primary index to grazing intensity. Litter was defined as dead, mostly horizontally-oriented, residual cover that contacted a meter stick at measuring points. Averages were based on 100 samples recorded when the meter stick used with the Robel pole was placed at the 4 cardinal directions to make a sighting on the pole. Twenty-five Robel pole sampling stations were located equi-distance (~ 15.4 m apart) along the middle of the long dimension of 400 x 200-m plots. Litter depths averaging > 10 cm were considered to indicate light grazing, < 5 cm heavy grazing, and readings in-between considered moderate grazing.

Determination of prairie type. Prairie type was determined by topographic position and the presence of plants characteristic of dry, mesic, wet, and brush prairie. To further characterize each plot, 20 samples were taken within each plot to estimate plant species composition, total canopy, bare ground, and percent cover by growth form (graminoid, forb, and woody) using a Daubenmire frame (Daubenmire 1959). Dry, mesic, and wet prairie plots had less than 10% woody cover while brush prairie plots had a minimum cover of 10% woody vegetation. Brush plots included both wet and dry prairie types.

Bird censusing The strip transect method (Stewart and Kantrud 1972) was used to count birds. Transects 400 m x 100 m wide (~ 4 ha) were used and these constituted study plots. Each plot was censused twice; once during the first 2 weeks of June and again during the first 2 weeks of July. Birds were censused between 0500 and 1000 when there was no rain, no dense fog, and wind speeds below 25 kmph. Censusing was not done when cows were in the transect area. Bird fly-overs were noted, but not included unless their behavior suggested an attachment to a plot.

RESULTS:

Litter depth (LD) and visual obstruction readings (VOR) were measured in all plots (Table 2). LDs ranged from a low of 0.3 cm (heavily grazed) to a high of 16.9 cm (lightly grazed). Predictably, VORs tended to be greater under light grazing and less under heavy grazing. However, dry and wet prairie plots averaged the highest VOR under moderately-grazed conditions.

Daubenmire data for measures of coverage are summarized (Tables 3 and 4). One might expect to see total canopy increases under lighter grazing, however, this trend was only evident in dry and wet prairie plots. Wet prairie plots showed an overall decrease in graminoid cover as grazing intensity increased, while brush prairie plots increased in graminoid cover when grazing intensity increased. The highest overall graminoid cover readings occurred on lightly-grazed,

Table 2. Visual obstruction readings (dm) and litter depths (cm) for bird plots, 2000 and 2001.

GRAZING INTENSITY	PRAIRIE TYPE[a]																			
		DRY					MESIC					WET					BRUSH			
	Plot	LD	SE	VOR	SE	Plot	LD	SE	VOR	SE	Plot	LD	SE	VOR	SE	Plot	LD	SE	VOR	S
Lightly grazed	**13**[b]	10.5	4.24	1.42	0.93	**25**	12	4.22	1.89	0.46	**9**	19.7	7.94	2.33	0.89	**34**	10.2	3	1.95	0.
	10	10.7	5.64	1.62	1.28	**26**	12.8	2.2	1.92	0.27	**27**	11.4	3.27	1.77	0.38	**3**	14.2	5.55	3.62	1.
	24	13.3	4.81	1.44	0.46	**36**	11.5	3.47	1.47	0.46	**15**	12.1	4.4	2.43	0.54	**2**	13.5	4.11	2.66	0.
	51	10.3	5.42	1.93	1.42	**39**	14.1	4.69	3.98	1.38	**69**	14.9	6.61	4.16	0.94	**44**	16.9	7.18	6.3	2.
	50	10.5	5.34	1.82	0.82	**64**	14.7	5.24	2.85	0.69	**57**	10.1	4.22	1.58	0.64	**55**	11.3	4.59	3.34	1.
	61	10.4	2.98	2.16	0.88	**63**	14.7	5.56	2.4	0.76	**56**	10.2	3.93	1.84	0.89	**72**	15	6.93	2.64	0.
Moderately grazed	**21**	6.9	2.26	1.54	0.37	**5**	6.55	3.19	1.89	0.65	**35**	8	2.19	2.01	0.35	**14**	9.5	4.52	1.37	0.
	20	6.85	1.98	1.6	0.29	**4**	7.55	4.26	1.81	0.74	**6**	8.8	2.94	2.45	0.46	**8**	5.95	1.74	1.14	0.
	19	7.35	1.92	1.56	0.39	**7**	6.15	3.94	1.7	0.39	**28**	7.85	3.18	2.25	0.58	**32**	7.65	1.99	1.57	0.
	67	6.5	3.63	2.31	0.83	**62**	5.1	2.75	1.46	0.73	**46**	7.5	2.95	3.52	1.66	**71**	5.3	3.27	3.12	1.
	68	6.8	2.79	1.54	1	**45**	9.5	2.84	3.33	1.62	**42**	7.15	2.56	2.98	0.87	**48**	7.4	2.82	2.65	1.
	66	7.75	2.75	2.06	0.51	**40**	7.4	1.56	1.32	0.93	**59**	6.15	4.59	2.91	0.58	**70**	5.75	1.87	2.69	
Heavily grazed	**12**	2.45	3.05	0.95	0.45	**33**	3.5	2.55	0.9	0.27	**16**	1.7	1.39	1.73	0.55	**23**	4.6	5.62	1.92	1.
	22	2.65	1.41	1.21	0.39	**1**	3.35	2.13	0.98	0.32	**29**	2.7	2.3	1.17	0.44	**11**	2.95	3.29	1.06	0.
	18	1.55	2.43	0.91	0.52	**31**	4.8	2.76	1.19	0.32	**30**	3.15	2.77	1.4	0.43	**17**	1.05	2.16	0.83	0.
	53	1.5	1.19	0.66	0.18	**58**	0.3	0.55	0.63	0.17	**47**	1.85	2.25	1.94	0.75	**54**	1.3	1.51	1	0.
	65	2.85	1.93	1.71	0.61	**37**	0.4	0.78	1.07	0.63	**60**	1.55	1.26	2.19	0.76	**38**	0.4	0.84	0.16	
	43	1.4	1.26	2.29	1.23	**52**	0.6	1.08	0.69	0.16	**41**	1.7	1.44	3	1.25	**49**	1	1.61	1.37	0.

[a] LD = mean litter depth. VOR = mean visual obstruction reading. SE = standard error.
[b] Plots numbered < 37 are from 2000 and plots ≥ 37 are from 2001.

Table 3. Canopy coverage (%) vegetation data for breeding bird plots by prairie type and grazing intensity, 2000.[a]

GRAZING INTENSITY	PRAIRIE TYPE																							
	DRY						MESIC						WET						BRUSH					
	Plot	TC	BG	G	F	W	Plot	TC	BG	G	F	W	Plot	TC	BG	G	F	W	Plot	TC	BG	G	F	W
Lightly grazed	**61**	65	35	26	24	3	**63**	38	62	17	11	0	**69**	31	69	16	9	1	**44**	48	52	31	20	2
	50	33	67	11	17	3	**64**	31	69	10	22	0	**56**	44	56	23	9	1	**55**	55	45	15	22	5
	51	39	66	9	36	1	**39**	50	50	26	13	0	**57**	46	54	35	12	0	**72**	39	62	4	15	7
Moderately grazed	**66**	29	71	17	9	0	**40**	53	47	20	13	0	**42**	35	65	27	11	0	**48**	47	53	22	11	3
	67	29	71	11	12	0	**45**	40	60	16	12	2	**46**	35	65	23	8	2	**71**	33	67	14	9	5
	68	30	70	13	8	0	**62**	52	47	26	33	0	**59**	40	60	20	11	2	**70**	40	60	20	8	1
Heavily grazed	**65**	41	59	25	10	0	**37**	64	36	21	44	2	**41**	37	64	25	9	0	**38**	54	46	19	23	8
	53	22	78	7	10	2	**52**	22	78	6	20	0	**47**	38	62	26	7	0	**49**	56	44	33	32	4
	43	25	75	20	9	0	**58**	28	73	12	13	0	**60**	30	70	18	8	0	**54**	41	59	14	18	4

[a] **Daubenmire method.** Plot = transect number, TC = total canopy coverage, BG = bare ground, G = graminoid, F = forb, W = woody.

Table 4. Canopy coverage (%) vegetation data for breeding bird plots by prairie type and grazing intensity, 2001.[a]

GRAZING INTENSITY	PRAIRIE TYPE																							
	DRY						MESIC						WET						BRUSH					
	Plot	TC	BG	G	F	W	Plot	TC	BG	G	F	W	Plot	TC	BG	G	F	W	Plot	TC	BG	G	F	W
Lightly grazed	**10**	18	82	9	7	0	**36**	53	47	30	7	0	**15**	54	46	32	8	1	**3**	32	68	10	7	4
	13	51	49	7	24	1	**26**	43	57	25	10	0	**27**	40	60	29	6	0	**34**	60	40	34	6	7
	24	45	55	34	4	0	**25**	33	67	14	7	1	**9**	51	49	27	5	1	**2**	20	80	3	10	7
Moderately grazed	**19**	38	62	23	10	0	**4**	36	64	14	13	1	**28**	41	59	31	4	0	**32**	39	61	11	6	1
	20	32	68	19	8	0	**7**	42	58	22	16	0	**6**	46	54	24	7	1	**8**	44	56	42	8	7
	21	31	69	14	23	0	**5**	43	57	19	14	0	**35**	56	44	41	6	0	**14**	22	78	9	15	2
Heavily grazed	**22**	44	56	30	5	0	**31**	39	61	14	11	0	**30**	29	71	25	4	0	**17**	61	39	34	9	3
	18	37	63	12	21	2	**1**	15	85	6	7	0	**29**	30	70	23	4	0	**11**	35	65	6	27	4
	12	9	91	3	6	0	**33**	32	68	14	6	0	**16**	30	70	18	9	1	**23**	34	66	15	10	1

[a] **Daubenmire method.** Plot = transect number, TC = total canopy coverage, BG = bare ground, G = graminoid, F = forb, W = woody.

wet prairies. Forb readings were very sporadic. The lowest average readings occurred on moderately- grazed brush prairies and the highest on lightly-grazed, dry prairie plots.

A plant species list was compiled by prairie type for plants with a frequency of occurrence >20 % (Appendix 1). Brush prairie plots had 99 species, mesic prairie 87, dry prairie 82, and wet prairie had 71 different species.

A total of 18 bird species and 941 individuals were censused in 72 plots (Table 5). Savannah sparrows were clearly the most abundant at 348 breeding birds (approximately 36% of total), and the most widely distributed, occurring in all prairie types. Grasshopper sparrows, while more restricted in distribution, were the second most abundant at 121 and found primarily on dry prairie. Clay-colored sparrows, bobolinks, and western meadowlarks followed in abundance ranking (Table 5). Clay-colored sparrows were found primarily in brush plots but on all other prairie types, providing there was brush or other woody vegetation present. They also had a very high frequency of occurrence on lightly-grazed pastures (about 92%). Western meadowlarks were never very abundant on any site, but were present at least once on every prairie type and grazing intensity combination. Bobolinks occurred mostly on wet, brush, and mesic prairie under light to moderate grazing and were generally observed perching at a height of about 1 m suggesting the importance of song perches. LeConte's sparrows were the sixth most abundant bird (35) and found in all prairie types except heavily-grazed pastures. Sedge wrens were quite abundant but only on wetter prairie sites.

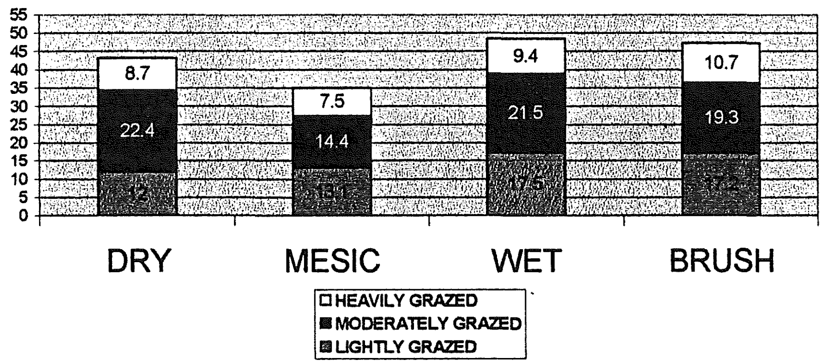
Table 5. Summary of breeding bird data for 2000/2001 survey.

Species	Total birds surveyed	Frequency of occurrence	% of birds by prairie type				% of birds by grazing intensity		
			Dry	Mesic	Wet	Brush	Light	Moderate	Heavy
Savannah sparrow	348	88.9	12	25	39	24	36	49	15
Grasshopper sparrow	121	37.5	74	14	0	12	22	64	14
Clay-colored sparrow	97	54.2	21	12	5	62	43	34	23
Bobolink	84	48.6	5	27	44	24	45	46	9
Western meadowlark	72	66.7	36	29	18	17	26	35	39
LeConte's sparrow	34	19.4	3	15	53	29	41	56	3
Red-winged blackbird	34	31.9	18	9	41	32	24	35	41
Common yellowthroat	28	31.9	14	29	4	53	43	39	18
Sedge wren	26	16.7	0	12	62	26	58	38	4
Upland sandpiper	19	16.7	42	16	26	16	21	58	21
Marbled godwit	19	12.5	47	10	32	11	11	63	26
Killdeer	12	12.5	25	8	42	25	0	17	83
Song sparrow	11	15.3	0	27	27	46	9	36	55
Brewer's blackbird	10	9.7	30	20	10	40	10	0	90
Chestnut-collared longspur	8	2.8	100	0	0	0	0	100	0
Dickcissel	8	4.2	25	0	0	75	25	63	12
Vesper sparrow	8	8.3	50	0	38	12	12	63	25
Sharp-tailed sparrow	2	1.4	0	0	100	0	100	0	0
total	941								

Two state endangered species, chestnut-collared longspurs and loggerhead shrikes, were observed during the study as well as 2 species of special concern; sharp-tailed sparrows and marbled godwit. These birds are uncommon to rare in the study area.

This study suggested that moderate grazing intensity was beneficial to breeding prairie birds since, in all prairie types, the average number of breeding birds was highest on moderately grazed sites (Fig. 2). Greater numbers occurred in wet and brush prairie probably due to their greater structural complexity.

Fig. 2. Mean number of breeding birds compared between prairie type and grazing intensity, 2000 and 2001.



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Appendix 1. Plant species list from 2000 and 2001 bird survey arranged by prairie type.[a]

DRY	MESIC	WET	BRUSH
Absinthe wormwood	Alfalfa	Canada anemone	Absinthe wormwood
American pennyroyal	Big bluestem	Canada goldenrod	Alum root
Big bluestem	Black medic	Common dandelion	Big bluestem
Black medic	Blackseed plantain	Death camas	Black medic
Blue grama	Broad-leafed panicum	Dogbane	Broad-leafed panicum
Broad-leafed panicum	Buckbrush	Field bindweed	Buckbrush
Buckbrush	Canada bluegrass	Foxtail barley	Canada bluegrass
Canada bluegrass	Canada goldenrod	Golden alexanders	Canada goldenrod
Canada goldenrod	Chickweed	Heal-all	Common dandelion
Chickweed	Common dandelion	Indian grass	Common milkweed
Common dandelion	Common milkweed	Intermediate wheatgrass	Common ragweed
Common milkweed	Common ragweed	Kentucky bluegrass	Dark-eyed susan
Common ragweed	Dark-eyed susan	Many-flowered aster	Dogbane
Curlycup gumweed	Evening primrose	Maximilian sunflower	Flodman's thistle
Dark-eyed susan	Golden alexanders	Missouri goldenrod	Golden alexanders
Evening primrose	Harebell	Northern bedstraw	Harebell
Flat-topped aster	Hoary puccoon	Prairie cordgrass	Hoary puccoon
Flodman's thistle	Indian grass	Prairie cinquefoil	Indian grass
Hairy golden aster	Intermediate wheatgrass	Prairie ragwort	Intermediate wheatgrass
Hoary alyssum	Kentucky bluegrass	Prairie rose	Junegrass
Hoary puccoon	Leafy spurge	Purple prairie clover	Kentucky bluegrass
Intermediate wheatgrass	Little bluegrass	Redtop	Leafy spurge
Junegrass	Long-headed coneflower	Silky aster	Licorice plant
Kentucky bluegrass	Many-flowered aster	Spotted bee balm	Little bluestem
Little bluestem	Missouri goldenrod	Switchgrass	Many-flowered aster
Long-headed coneflower	Mountain mint	Tall meadow rue	Maximilian sunflower
Many-flowered aster	Mouse-eared chickweed	Tall blazing star	Mountain mint
Needle and thread	Northern bedstraw	White clover	Goldenrod sp.
Plumeless thistle	Plumeless thistle	Whorled loosestrife	Northern bedstraw
Porcupine grass	Prairie ragwort	Wild mint	Pasqueflower
Prairie onion	Prairie rose	Wild strawberry	Porcupine grass
Prairie sage	Prairie smoke	Yellow nutsedge	Prairie cordgrass
Prairie thistle	Purple prairie clover		Prairie cinquefoil
Purple coneflower	Pussytoes		Prairie ragwort
Purple prairie clover	Quackgrass		Prairie rose
Quackgrass	Red clover		Prairie smoke
Red clover	Redtop		Purple prairie clover
Redtop	Shrubby cinquefoil		Pussy toes
Sand dropseed	Scurf pea		Quackgrass
Scarlet gaura	Side-oats grama		Red clover
Side-oats grama	Silver leadplant		Redtop
Silver leafed psoralea	Silver-leafed psoralea		Reed canarygrass
Smooth brome	Smooth brome		Sandbar willow
White clover	Stiff sunflower		Silver leadplant
Yarrow	Switchgrass		Smooth brome
Yellow flax	Tall meadow rue		Spiked lobelia
Yellow sweetclover	Tall-blazing star		Switchgrass
	Thimbleweed		Tall meadow rue
	Timothy		Tall blazing star
	White clover		Thimbleweed
	White sweetclover		Timothy
	Wild bergamot		White clover
	Witchgrass		Whorled loosestrife
	Yarrow		Wild bergamot
	Yellow sweetclover		Wild strawberry
			Yarrow

[a] *Included plants had at least a 20% frequency of occurrence (based on 20 samples).*

Appendix 2. Total birds observed during 2000/2001 breeding bird surveys.

Species	Total individuals
Savannah sparrow	357
Grasshopper sparrow	121
Clay-colored sparrow	95
Bobolink	83
Western meadowlark	74
Leconte's sparrow	35
Red-winged blackbird	33
Common yellowthroat	28
Sedge wren	26
Upland sandpiper	19
Marbled godwit	19
American goldfinch	16
Eastern kingbird	14
Killdeer	12
Chestnut-collared longspur	11
Song sparrow	11
Brewer's blackbird	10
Dickcissel	8
Vesper sparrow	8
Tree swallow	5
Brown-headed cowbird	5
Mourning dove	5
Yellow warbler	4
Baltimore oriole	4
Greater prairie chicken	3
Common snipe	3
Northern flicker	3
Eastern bluebird	3
American robin	3
Sharp-tailed sparrow	2
Sandhill crane	2
Brown thrasher	2
American redstart	1
Black-capped chickadee	1
Hairy woodpecker	1
Canada goose	1
Northern harrier	1
American crow	1
Red-tailed hawk	1
Yellow-headed blackbird	1
Great blue heron	1
Western kingbird	1
Loggerhead shrike	1

Grassland Bird Reproductive Success on Rotationally Grazed Pasture and Ungrazed Conservation Reserve Program (CRP) Land in West Central Minnesota

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Abstract: We compared nest success of grassland passerine birds on rotationally grazed prairie versus ungrazed CRP prairie on 261 ha of contiguous grassland in west central Minnesota. Twenty-two percent of the study site was in the CRP program for 12+ years, and the remainder was rotationally-grazed by 99 cow/calf pairs and 4 bulls from June through October for the past 10 years. Cattle grazed a paddock for 2-3 days, leaving paddocks to rest 20-30 days between grazing periods. We found 60 nests by systematically searching 14, 1-ha plots and monitored nests every 3 days until fledging or depredation. Clay-colored Sparrows, Vesper Sparrows, and Grasshopper Sparrows comprised 92% of all nests monitored. Daily nest survival for these species was 0.93 in the grazed prairie, and 0.94 in the ungrazed CRP prairie ($P = 0.59$). Rotational grazing at a density of 2.41 animal units/hectare had no detectable effect on nest success of small passerines compared to ungrazed CRP land in 2001.

INTRODUCTION

Grassland bird species have shown steeper, more consistent, and more widespread declines than any other bird guild in North America (Knopf 1994). With native prairie covering less than 1% of its original range in Minnesota, prairie nesting birds have become largely dependent on privately held, primarily non-native, agricultural grasslands for breeding habitat. As commodity prices fell during the 1990's, and farmers looked for new sources of revenue, many pastures were plowed and seeded to row crops. Recent declines of grassland bird species in the Midwest correlate with declines in regional area of pastures and hay fields (Herkert et al. 1996).

During this same period, some farmers replaced their reliance on government commodity programs with independent, pasture-based beef cattle operations. While most grassland or range farmers practice continuous or seasonal grazing, where cattle are let out into a large paddock for the year or for a season, a growing number of farmers in the Midwest find rotational grazing more cost effective and efficient than continuous grazing (Undersander et al. 1993).

The Conservation Reserve Program (CRP) is a multi-year, government set-aside program that has successfully slowed topsoil runoff and provided habitat for wildlife, including birds (Kantrud et al. 1981). As CRP fields have aged without being hayed, burned, or grazed, some research has indicated that their usefulness to birds has declined (Herkert et al. 1996, Johnson and Temple 1990, Koford and Best 1996).

Past research examining grassland bird reproductive success on grazed fields focused primarily on waterfowl (Barker et al. 1990, Belanger and Picard 1999) and upland game birds (George et al. 1979, Holechek et al. 1982, Manske et al. 1987) with few exceptions. Herkert et al. (1996) pointed out the need for more data on grassland bird demographics and especially studies that differentiate habitat *sources* from those that are *sinks*.

In North Dakota, lower nest success was reported for upland sandpipers on fields grazed in May and June with stocking densities of 3.7 animals/ha, although little evidence indicates that a particular seasonal grazing system is responsible for annual variation in nest success (Bowen and Kruse 1993). In Saskatchewan greater numbers of grassland passerine species used grazed more than ungrazed plots for feeding, but nested elsewhere (Dale 1984).

Trampling by cattle can reduce nest success. Jensen et al. (1990) used imitation nests of clay pigeons to document that trampling increased exponentially over time for all stock densities and that stock densities above 2.5 AU/ha could result in significant disturbance of ground-nesting birds. Paine et al. (1996) used unwashed pheasant eggs to measure nest success in intensive rotationally grazed (IRG) pastures in Wisconsin and found that trampling damaged a mean of 75% of the imitation nests.

Ungrazed grasslands (grasslands grazed previous years but not the current year) had higher grassland bird diversity, densities, nesting success, and productivity compared to continuously grazed, and IRG grasslands in Wisconsin (Temple et al. 1999). Continuously grazed pastures with 2.5-4 animals/ha tended to have the lowest diversity and densities and intermediate nest success and productivity. Rotationally grazed pastures with 40-60 animals/ha had intermediate diversity and densities and the lowest nest success and productivity.

Our objectives were to measure grassland bird reproductive success, specifically nest survival, in rotationally-grazed pastures and ungrazed Conservation Reserve Program grasslands. To accomplish this we located and monitored bird nests and recorded vegetation characteristics in both habitats.

STUDY AREA

Our 371-ha (645 a) study site was located 9.7 km (6 mi) north of Evansville in Douglas County, Minnesota and included parts of Sections 2, 3, and 11 in Lund Township (Figure 1). The site was in the prairie pothole ecoregion and had a varied topography that ranged from 369 m to 430 m (1210 ft -1410 ft), with small lakes dammed at ~381 m (1250 ft), and Lake Christina at 369 m (1210 ft). The site's hilly nature, rock strewn landscape, and sandy soil are all possible reasons why most of the area was never plowed and vegetation in the unforested areas consists primarily of native grassland plant species.

The site was fenced and partitioned into 16 paddocks varying in size from 5.8 to 36.3 ha (Figure 2). Eighty hectares (139 a) or 18.3% were not part of the rotational grazing scheme and were enrolled in the Conservation Reserve Program (CRP). The CRP area was further divided into 68 ha (118 a) of contiguous and primarily native grassland (paddocks 10 and 11), and 12.2 ha (21 a) of more recently planted, homogeneous, non-native grasses (paddock 12). Time enrolled in CRP varied with these 3 paddocks with paddock 10 having been enrolled for 18 years, paddock 11 for 16 years, and paddock 12 for 12 years (as of summer 2001).

Vegetation on the site varied from sparse grasses and forbs on some of the rocky hilltops to deep lush grass in valleys, western snowberry (*Symphoricarpos occidentalis*) and smooth sumac (*Rhus glabra*) in numerous areas, expanding aspen clones (*Populus tremuloides*), cottonwood (*Populus deltoides*) bottomland, groves of bur oak (*Quercus macrocarpa*) savannah, and dense woodlots tangled with hawthorn (*Crataegus* sp.). Numerous small lakes were surrounded by dense willow (*Salix* spp.) thickets.

The grazing regimen consisted of 16 paddocks, 12 of which were arranged like spokes of a wheel around a centrally positioned water hole, salt licks, and mineral feeders (Figure 2). This grazing system has been employed on the site for the last 18 years and is fashioned after guidelines in *Holistic Resource Management* (Savory 1988). Paddocks that were grazed but with out access to the central water hole allowed cattle access to Lake Christina or had small in-pasture potholes. Six of the grazed paddocks had small lakes in addition to the central water hole.

Cattle included 99 cow/calf pairs (1 cow and her calf are an Animal Unit or AU), began grazing the area 1 June, and were there through the fall. Four bulls were added 18 June. Grazed paddocks had an average grazing density of 4.35 animal units (AU) / hectare (or 2.5 AU/acre).

Landowner activities during the study were monitored but not altered as part of the study. An all-terrain vehicle was used to move cattle from paddock to paddock. The landowner also trapped and killed 14 raccoons near the road on the western end of paddock 11 in his effort to enhance duck nest success.

METHODS

Nest Search Plots and Nest Searches

We searched for nests in 14 plots, totaling 13.5 ha, located in 11 paddocks. Plots varied in size from 0.5 h to 1.5 h (Table 1). We located nest search plots > 100 m from forest edges and >100 m from wetlands to limit our encounters of species associated with those habitats (Figure 2). We located and monitored nests from 30 May to 5 August. We searched for nests primarily by walking slowly through grasslands sweeping a 2-m long, light-weight rod from side to side and noting the locations of flushing birds (hereafter, stick sweeping). We also located nests coincident with other activities or whenever a bird was observed flushing from a potential nest site. Often we found nests as we walked through the study area during early morning breeding bird surveys and during vegetation analysis. We monitored all nests found in and out of plots every 3 days until the chicks fledged or the nest was lost.

We collected nest and egg/nestling data carefully to minimize disturbance and attention drawn to the site. Observers glanced briefly at the nest before moving 30-50 meters away before recording nest data. We defined successful fledging as either observing fledglings in the vicinity of the nest, witnessing chipping adults with food near the empty nest, finding feather sheaths in the nests, or finding feces in or close to the nest. Nests that were not designated as either successful or unsuccessful in the field were later judged successful if the nest was intact and the young were within 48 h of estimated fledge time and date.

We recorded depredation events as characterized by a nest with only a flattened nest rim or one that has been physically pulled apart, or where egg shells are found scattered nearby and the area is quiet with no attending adults.

Indications of trampling included nests that had been tipped to the side and eggs had fallen out but were uneaten (broken and unbroken). Other signs were large cow pies very close to or on the nest, nest substrate eaten by cows revealed the nest and knocked it askew (presumably causing parents to abandon), and nests that were stepped on and crushed.

We calculated daily survival (Mayfield 1961 and 1975, Bart and Robson 1982) for each nest for eggs, chicks, and overall. We used the following incubation and nestling periods, respectively: Clay-colored Sparrow, 11 and 8 days; Vesper Sparrow, 12 and 9 days; Grasshopper Sparrow, 11 and 9 days; Yellow Warbler, 11.5 and 10.5 days; American Goldfinch, 11 and 14 days; Eastern Kingbird, 17 and 17 days; Horned Lark, 11.5 and 10.5 days; and Brown Thrasher, 12.5 and 11 days.

We calculated interval survival by raising Mayfield daily survival to the number of days young (in both the egg and nestling stage) were in the nest before they fledged.

Surveys of Breeding Birds

We established breeding bird survey transects to determine the presence of all breeding grassland birds (diversity) and their relative abundance on the study area. We surveyed both grazed and ungrazed portions of the study area. Three 100-m wide line transects were established containing survey points every 50 m along the midline of the transect (Lancia et al. 1994). At each point, we recording birds identified by sight and sound within a 50-m radius from the survey point for 5 minutes. We surveyed transects on 10 June, 17 June, and 7 July; sampling 7 ha of ungrazed and 13 ha of grazed grassland. The eastern horseshoe transect was 600-m long and located in grazed paddocks 4, 5, and 6. The northwestern transect was 700 m long and located in grazed paddocks 1 and 2. The southwestern transect was 700 m long and located in ungrazed paddocks 10 and 11(see Figure 3). Transect location and configuration was designed to minimize overlap with nearby wetland, brushy, or wooded areas. Surveys began at 0500, and ended before 0900. All three transects were sample each survey morning, and the plot sampled first was randomly determined, without replacement, among the 3 transects.

Nest Vegetation Measurements

We recorded vegetation characteristics at 49 nest sites within 1 week after each nest was found empty. We measured percent cover, density of grass, vegetation height, litter depth, and number of woody stems at the nest and 4 m from the nest in each cardinal direction and found averages of the 5 readings for each variable. We used a Daubenmire frame (Daubenmire 1959) to estimate percent cover of grass, forb, downed litter, standing litter, woody stems, soil, cow manure, and rock and found averages of the 5 readings for each variable. Vegetation density, or visual obstruction readings (VOR) at the nest site and 4 m from the nest in each cardinal direction was measured using the Robel pole (Robel et al. 1970), and the mean of the 5 (4 direction) means were found for each nest. Litter depth and vegetation height were measured with a meter stick at each corner of the Daubenmire frame and at each of the 5 locations for each nest (at the nest and 4 m in each cardinal direction). Data for nest vegetation includes only data for nests $\leq$ 50 cm. Grazed and ungrazed data were combined to characterize nest sites by species.

Nest Site Measurements

We recorded the slope and aspect of each nest as well as whether the nest was located at the top, middle, or bottom third of a hill. We noted the habitat edge closest to and second closest to the nest. Habitat edges included fences, forest, wetland, roads and recently prescribed fire areas.

Forage Use Measurements

We also measured the extent that forage was reduced by grazing by measuring a suite of the previously mentioned vegetation aspects at 20 random points immediately before, and 20 random point after grazing. Vegetation in the ungrazed paddocks was measured once per paddock at the end of the season.

Weather Data

Weather information was collected at the beginning and end of each field day including temperature, cloud cover, wind speed and direction, and a description of any noticeable precipitation.

RESULTS

Nest Success

We located and monitored 62 grassland bird nests of 9 different species; 51 in the grazed area and 11 in the ungrazed area (Table 2). We located nests of Clay-colored Sparrows (CCSP), Vesper Sparrows (VESP), Grasshopper Sparrows (GRSP), Yellow Warblers (YWAR), Horned Lark (HOLA), Eastern Kingbird (EAKI), American Goldfinch (AMGO), Brown Thrasher (BRTH), and Mallard (MALL). Apparent nest success (number of successful nests/ number of nests found) for all species monitored was 37% (n = 51) in the grazed area and 27% (n = 9) in the ungrazed area. We were unable to determine the fate of 2 (18%) nests in the ungrazed area.

Clay-colored Sparrows, Vesper Sparrows, Grasshopper Sparrows, and Horned Larks located their nests < 50 cm. off the ground. For this subset of nests (n=52) we found that apparent success was 33% for the grazed area (n = 43) and 37.5% for the ungrazed area (n = 9) (Table 3). We were unable to determine the fate of 2 (18%) nests in the ungrazed area (Table 3).

Daily nest survival for ground-nesting birds (n = 51) was 0.91 for the grazed area and 0.93 for the ungrazed area (P = 0.43) (Table 4). Interval survival for ground nesters was 0.15 for the grazed area and 0.27 for the ungrazed area (P = 0.09) (Table 4). Only 33 of 51 nests hatched young, and of those, 19 nests fledged an estimated 60 young.

Trampling

Some nests appeared to be trampled by cattle. A few Vesper Sparrow nests that survived to fledge young were centimeters from heavily traveled cow trails. Overall, 1 nest was trampled in the ungrazed paddocks (n = 9), and 9 nests were trampled in the grazed paddocks (n = 41).

Breeding Bird Transects

We found grassland-, shrub- and tree-associated bird species on all 3 transects despite our design to survey only grassland birds (Figure 4). The highest densities of CCSP were in the ungrazed, shrubby, CRP land, whereas GRSP and VESP were most abundant in the grazed areas (Figure 5).

Nest Vegetation

Clay-colored Sparrows (n = 32) used nest sites with a means of 3.7% soil and 33.1% woody plants. In contrast, Vesper Sparrows (n = 13) used sites with a mean of 36.1% soil and 3.9% woody plants (Table 5).

As was to be expected in a grazing system, fences were by far the most common primary edge (Figure 6). Forest was the most common secondary edge (Figure 7).

Nest Sites

Vesper Sparrows (n = 13) choose the steepest sites with a mean of 12.7 (+/-6.57 sd) degrees slope, followed by Grasshopper Sparrows (n = 3) with a mean of 10.3 (+/- 1.52 sd) degrees and Clay-Colored Sparrows (n = 35) with a mean of 6.86 (+/- 4.24 sd) degrees slope.

Forage Use Measurements

The average loss of vegetation density because of grazing was 0.34 dm (0.14 dm SE, Table 6). Some grazed paddocks (7 and 9) appeared to gain vegetational density after grazing (Figure 8). We believe this is a function of the nature of the vegetation in those paddocks. In paddock 7 a large wetland with high grass density variability encompassed about 1/4 of the points and a similar pattern of vegetation loss was indicated by both before/after measurements. Paddock 9 was primarily smooth sumac and tall buckbrush, species not suited to measurement by the Robel pole. Sometimes as we were shaded by a canopy of smooth sumac we could see below the first decimeters of the Robel pole. Other times when the canopy of sumac was below the sighting stick of the Robel Pole only the top of the pole could be read. Paddock 12 was planted to a mixture of native and nonnative cover about a decade ago and had by far the tallest and most dense grassy vegetation. We observed very few birds in this paddock.

DISCUSSION

The goal of this research was to assess the reproductive success of grassland birds on two agricultural grassland treatments: rotational grazing and ungrazed Conservation Reserve Program (CRP) land. Daily survival was 0.93 and 0.94 for the grazed and the ungrazed sections, respectively and were not different (P = 0.6). Unfortunately, our comparison was hampered by a small number of nests in the CRP land.

Grasshopper Sparrows were more abundant in grazed areas than ungrazed and more abundant overall than numbers of nests found indicated. Vesper sparrows used sparsely vegetated nest sites with a higher percentage of visible bare ground, while Clay-Colored Sparrows used nests sites with a greater percentage of woody shrubs.

Although the closest edge to most nests was a fence, the second closest was a forest which is considered a fairly hard edge for grassland birds. Depending on the vicinity of the forest this could explain some of the high predation rates seen in this study. On the other hand, paddock 11 (CRP) had 14 raccoons taken out of it, presumably reducing the predator load for the westernmost paddocks, including both grazed and ungrazed areas.

Analysis of before and after measurements of grazed vegetation show that while forage was reduced, the method used to assess this change did not adequately represent vegetational changes in all paddocks. In the future a matched pairs design of before and after measurements may have greater accuracy and reduce the number of points that need to be measured. Despite these limitations, the results were consistent where paddocks were repeated, and the overall mean reduction of 3.4 cm (1.2 cm SE) indicated the moderate impact of cattle on vegetation at this site.

Weather that most likely affected nest success of some species included huge (2-5cm per hour) torrential downpours with tornados and lightening during the month of June. The weather was cold and rainy for days and local farm fields were so flooded that farmers received disaster relief funds. Later, mid-July temperatures became very hot and dry, and reduced rainfalls induced a month-long drought.

The survey of breeding birds indicate that nest counts by species in this case are a poor judge of which species are more prevalent in grazed or ungrazed areas. Instead nest analysis should be limited to nest fates, but not as an indication of density of that species in the area.

FUTURE DIRECTIONS

Since limited study of nest success has been done on actively used private pasturelands in Minnesota, this work can serve as a departure for further research on factors affecting grassland bird success. These can include slope and aspect of nest sites, nest substrate characteristics, bird species effects, proximity of nests to cattle water holes, time of day cattle are let into a new paddock, how the addition of bulls affects trampling incidences, how early in the season grazing begins, and effects on nests of using a motor vehicle to move cows vs. a cattle dog.

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Table 1. Characteristics of plots search for grassland bird nests in west central Minnesota, 2001.

Plot #	Area (ha)	Paddock #	Grazed Status	# Searches
1	1.0	2	Grazed	4
2	1.0	1	Grazed	4
3	1.0	11	Ungrazed	4
4	0.5	10	Ungrazed	4
5	1.0	9	Grazed	4
6	1.0	8	Grazed	4
7	0.5	7	Grazed	4
8	1.5	5	Grazed	4
9	1.0	5	Grazed	2
10	1.0	4	Grazed	3
11	0.75	3	Grazed	3
12	1.0	2	Grazed	3
13	1.0	1	Grazed	2
14	1.5	12	Ungrazed	3

Table 2. Number of successful and unsuccessful grassland bird nests, by species, in grazed and ungrazed plots in west central Minnesota, 2001.

	Grazed		Ungrazed		
Species (species code)	Success	Failure	Success	Failure	Unknown Fate
Clay-colored Sparrow (CCSP)	10	17	3	4	1
Vesper Sparrow (VESP)	2	11	0	0	0
Grasshopper Sparrow (GRSP)	2	0	0	1	0
Yellow Warbler (YWAR)	1	1	0	0	1
Horned Lark (HOLA)	1	0	0	0	0
Eastern Kingbird (EAKI)	1	0	0	0	0
American Goldfinch (AMGO)	1	0	0	0	0
Brown Thrasher (BRTH)	1	0	0	0	0
Mallard (MALL)	0	0	0	1	0
Species unknown	0	3	0	0	0
Totals	19	32	3	6	2

Table 3. Apparent nest success of all grassland birds combined in west central Minnesota, 2001.

	Grazed		Ungrazed	
	n	Apparent success	n	Apparent success
Ground nesting species (<50 cm from the ground)	43	33%	9	37.5%?
All Species	51	37%	11	27%

Table 4. Daily nest survival[1] (Mayfield 1960) of grassland birds in west central Minnesota, 2001.

Characteristic	n	Daily survival	Daily variance	Daily P-value	Interval estimate (19 days)	Interval variance	Interval P-value
Overall	62	0.9304	0.0001186		0.25394	0.00319	
Grazed	51	0.9277	0.0001514		0.24045	0.00367	
Ungrazed	11	0.9419	0.0005306	0.57	0.32043	0.02217	0.62
Ground nesters							
Overall	51	0.9116	0.0001873		0.17242	0.00242	
Grazed	43	0.9071	0.0002372		0.14911	0.00256	
Ungrazed	8	0.9332	0.0008337	0.43	0.26865	0.00249	0.09

[1] Mayfield 1961.

Table 5. Percent coverage of vegetation classes at grassland bird nest sites (means and standard errors) in west central Minnesota, 2001.

Bird species	n	% Grass	% Downed litter	% Standing litter	% Forb	% Soil	% Woody plants
CCSP	32	35.7 (+/-2.8)	11.6 (+/-2.2)	1.5 (+/-0.2)	14.3 (+/-2.1)	3.7 (+/-1.1)	33.1 (+/-3.2)
GRSP	3	40.6 (+/-12.8)	33.0 (+/-9.5)	4.8 (+/-0.9)	9.8 (+/-1.2)	11.7 (+/-3.5)	0.0 (+/-0)
VESP	13	26.9 (+/-3.4)	12.6 (+/-1.5)	3.9 (+/-0.7)	16.6 (+/-3.4)	36.1 (+/-4.5)	3.9 (+/-2.3)

Table 6. Visual Obstruction Reading (VOR) before and after rotational grazing in west central Minnesota, 2001.

	n	Mean and SE (dm)	Median	Minimum	Maximum
Before grazing	10	1.71 (+/-0.11)	1.74	1.05	2.40
After grazing	10	1.37 (+/-0.12)	1.35	0.77	2.01
Difference P		-0.34 (+/-0.13) P = 0.03			

Figure 1. Study are location of grassland bird study in west central Minnesota, 2001.

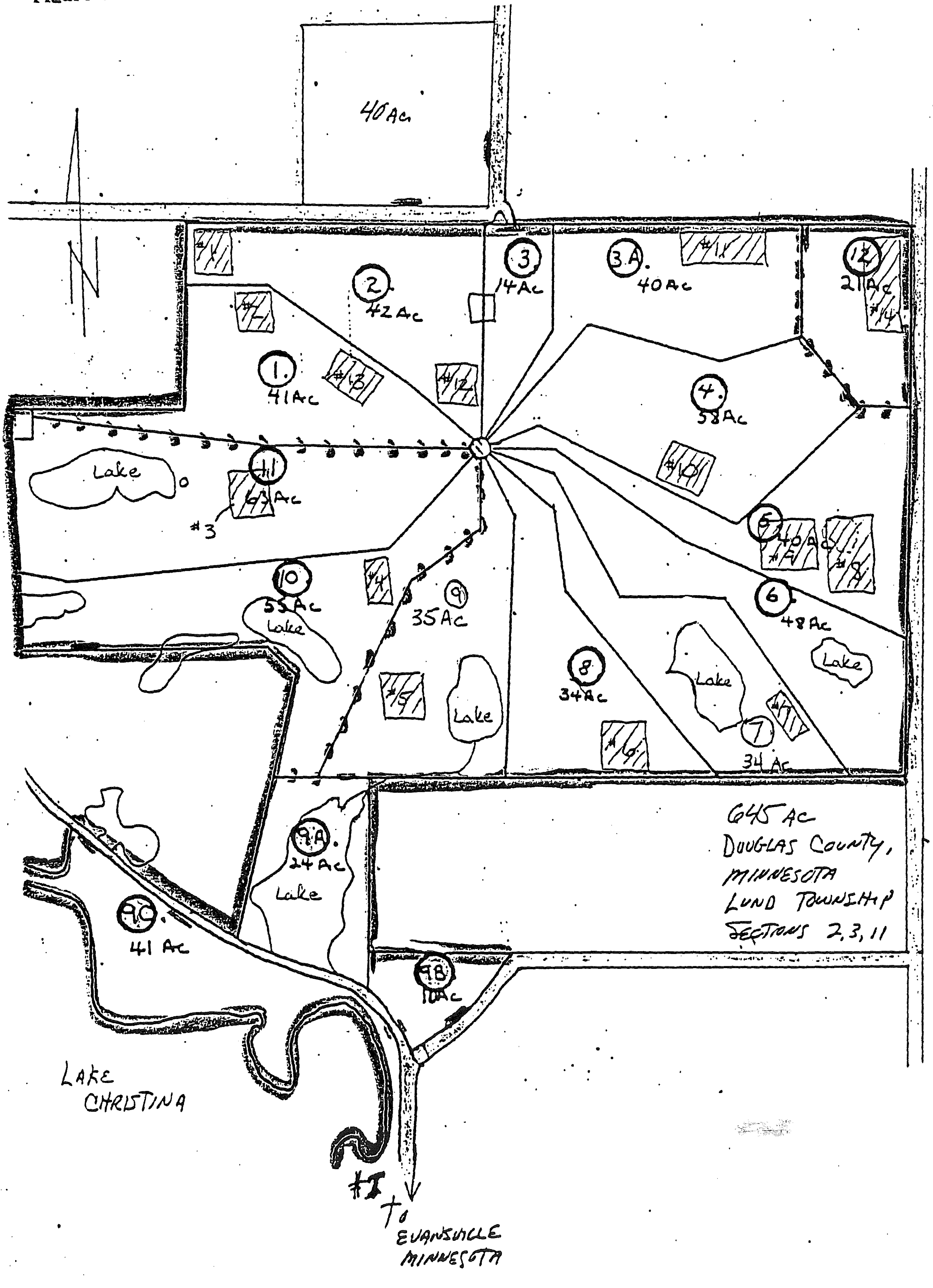


Figure 2. Fence layout of rotational grazing paddocks in west central Minnesota, 2001.

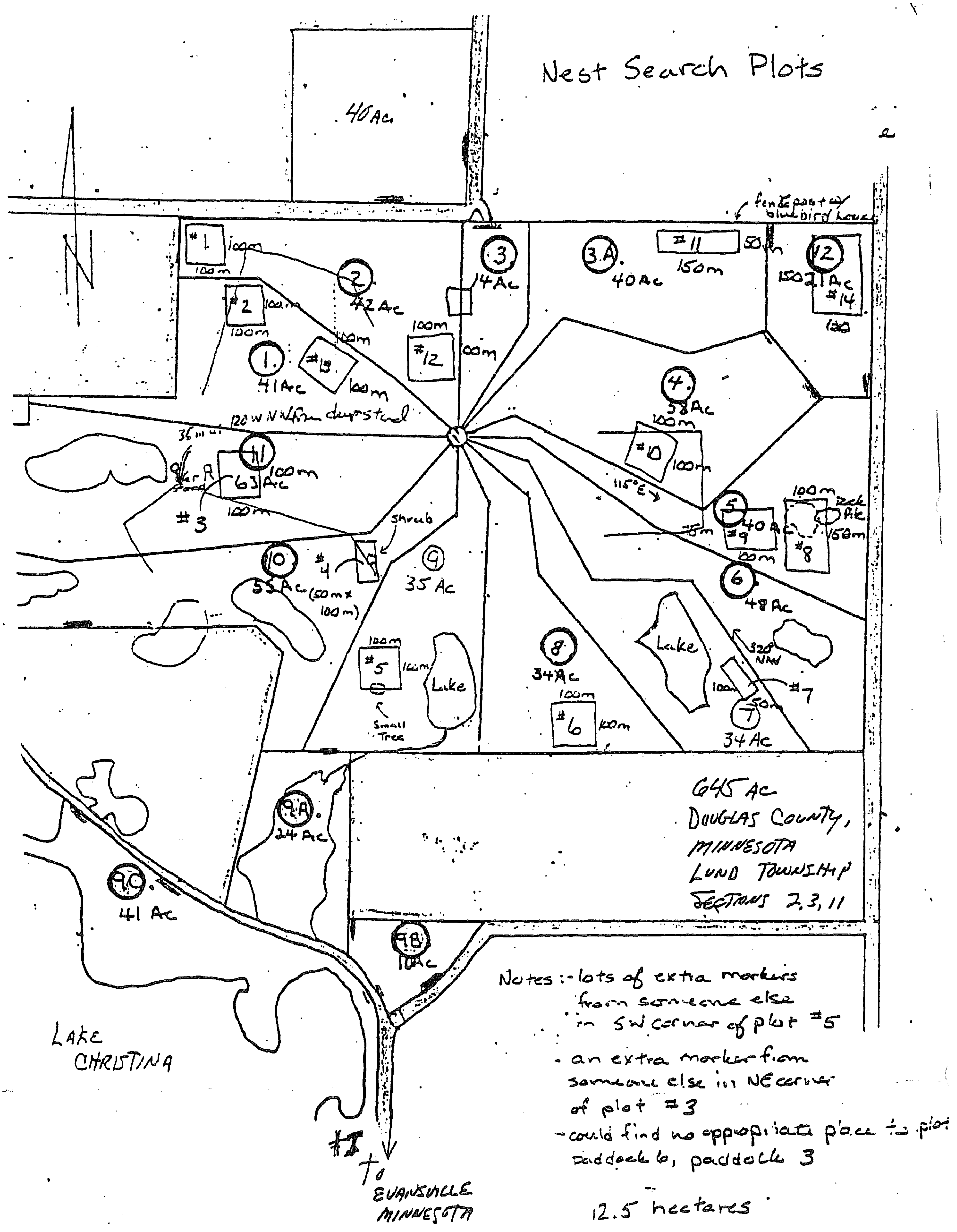


Figure 3. Location of transects to survey breeding grassland birds in west central Minnesota, 2001.

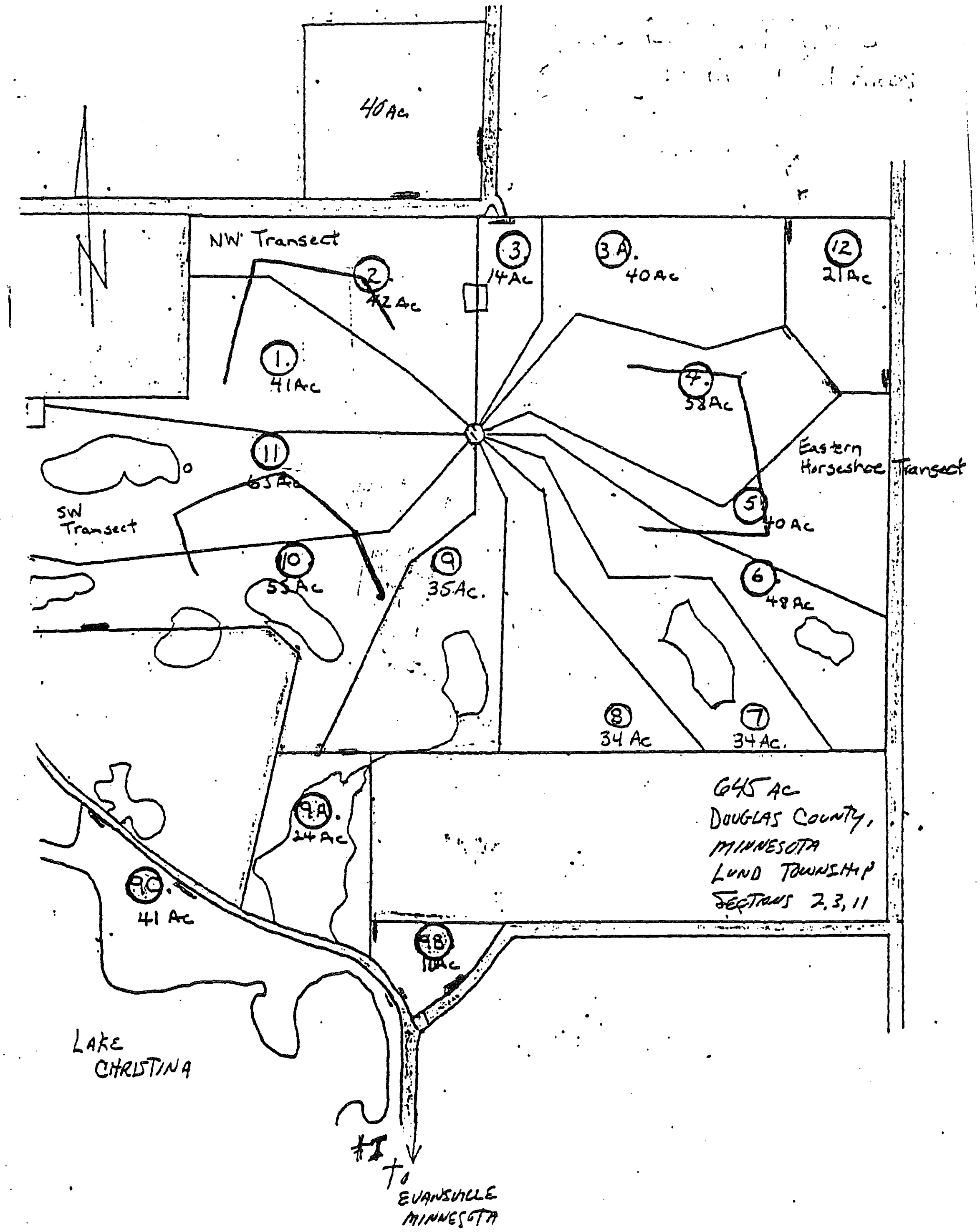


Figure 4. Abundance of breeding grassland birds in west central Minnesota, 2001.

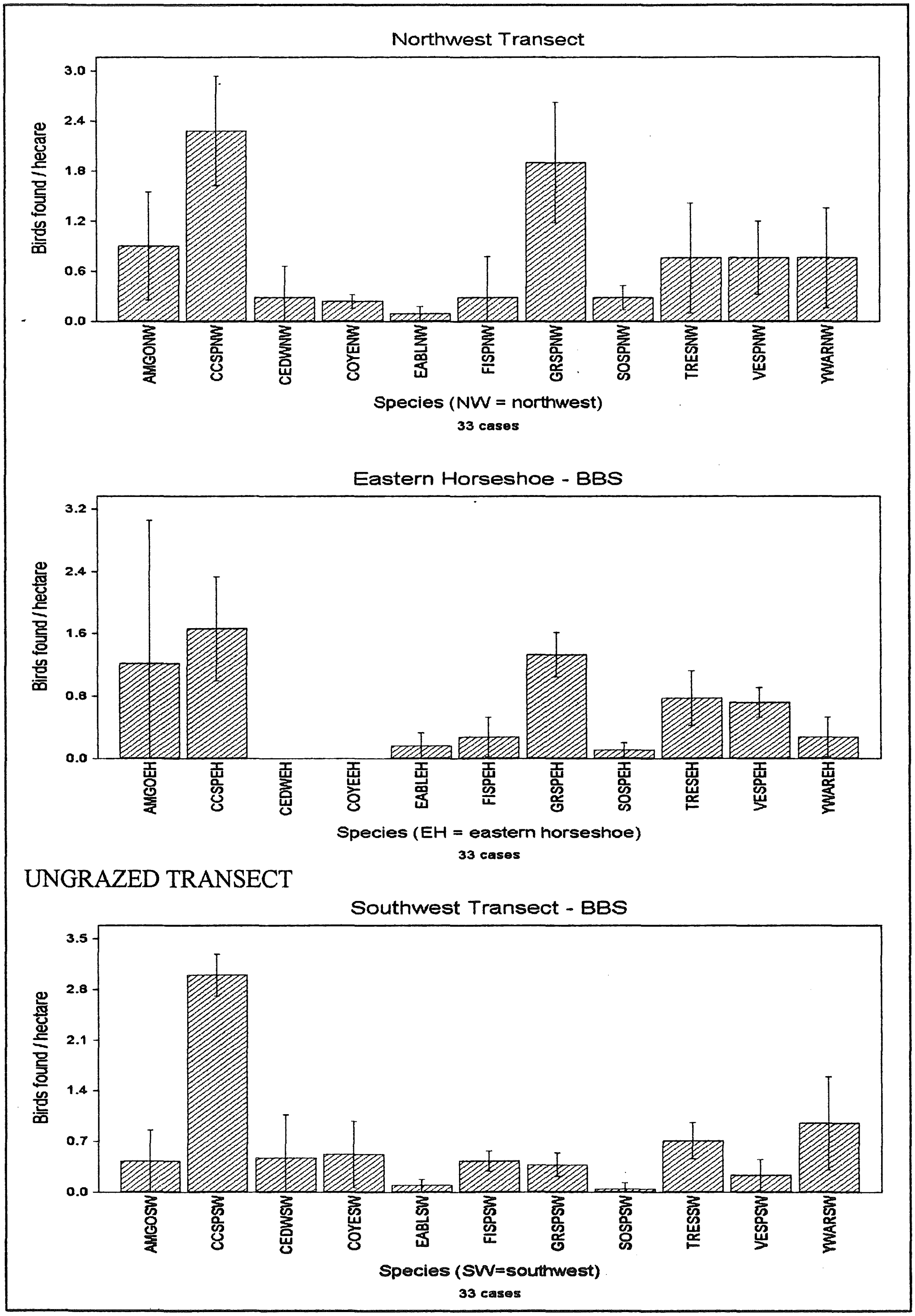


Figure 5. Density of breeding Grasshopper Sparrows, Clay-colored Sparrows, and Vesper Sparrows in west central Minnesota, 2001. First and second transects are grazed, the third is ungrazed.

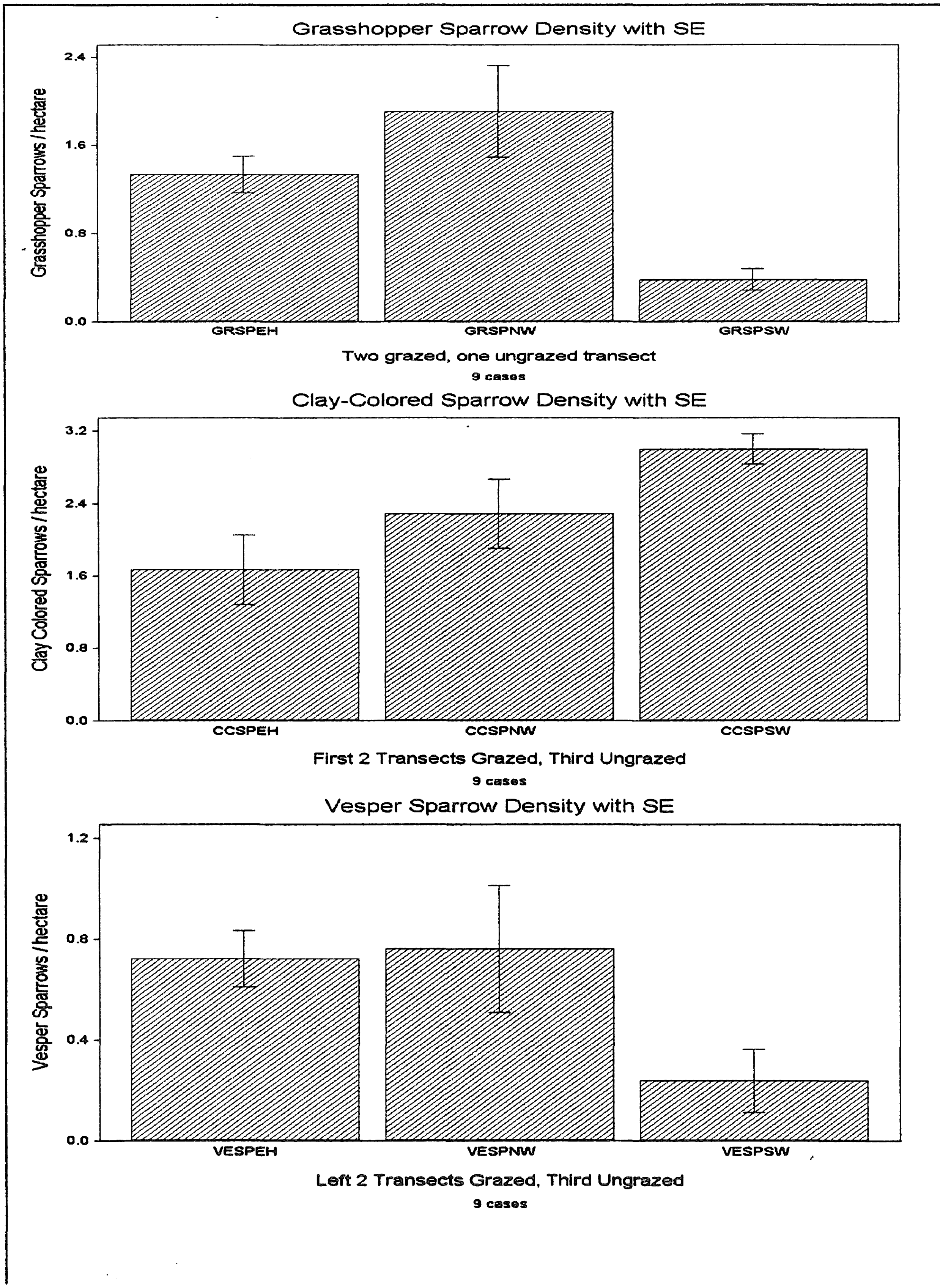


Figure 6. Type of edge closest to grassland bird nests in west central Minnesota, 2001

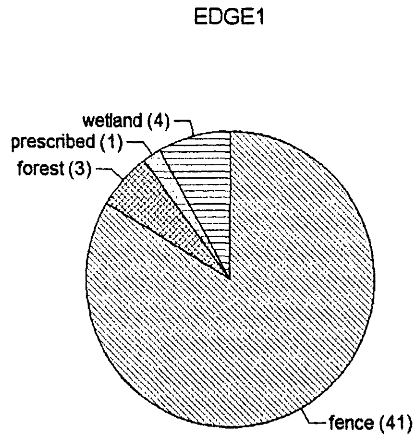


Figure 7. Type of edge second closest to grassland bird nests in west central Minnesota, 2001.

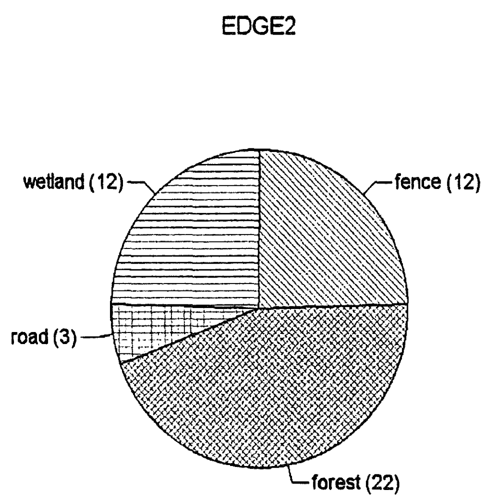
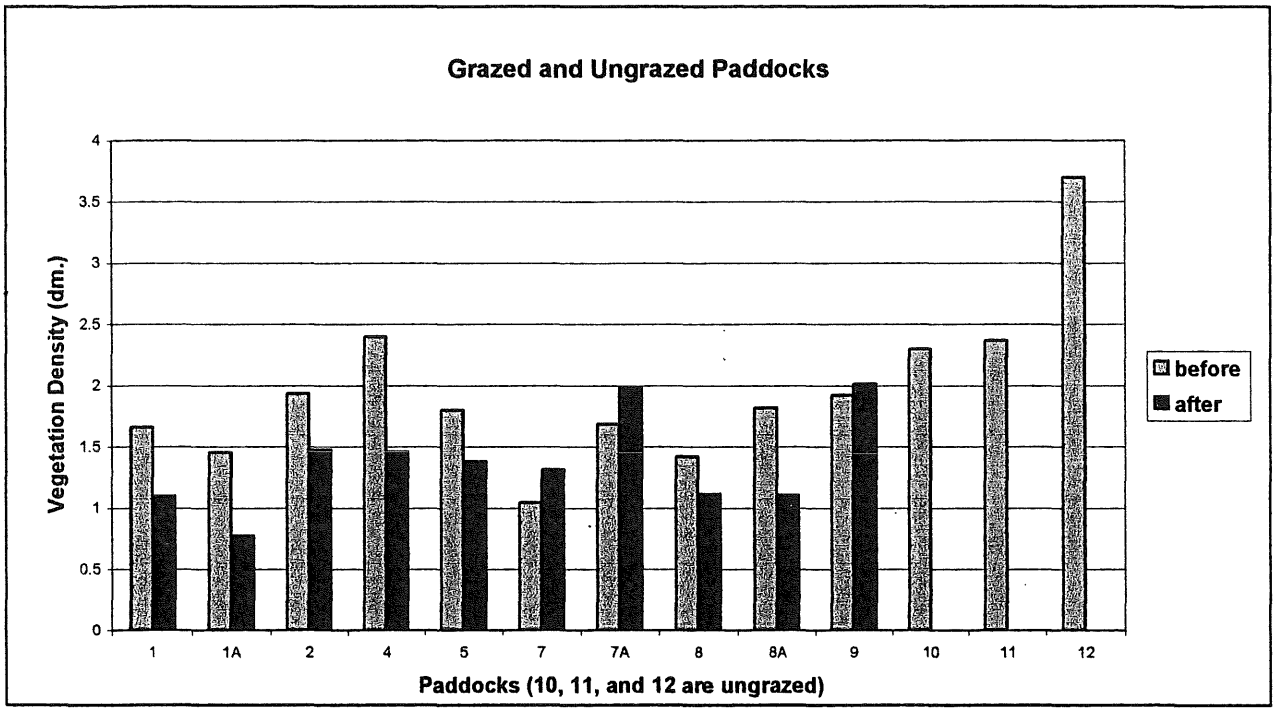


Figure 8. Visual obstruction reading before and after grazing in rotationally-grazed paddocks in west central Minnesota, 2001



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