2004

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Eric D. Salo
South Dakota State University

Kenneth F. Higgins
U.S. Geological Survey, kenneth.higgins@sdstate.edu

Bob D. Patton
North Dakota State University - Main Campus

Kristel K. Bakker
Dakota State University, kristel.bakker@dsu.edu

William T. Barker
North Dakota State University - Main Campus, William.Barker@ndsu.edu

See next page for additional authors

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by Eric D. Salo[1], Kenneth F. Higgins[2], Bob D. Patton[3], Kristel K. Bakker[4], William T. Barker[5], Brian Kreft[3] and Paul E. Nyren[3]*

[1]Wildlife and Fisheries Sciences Department, South Dakota State University, Brookings, SD 57007
[2]South Dakota Cooperative Fish and Wildlife Research Unit, U.S. Geological Survey, South Dakota State University, Brookings, SD 57007; terri.symens@sdstate.edu
[3]North Dakota State University, Central Grasslands Research Extension Center, Streeter, ND 58483
[4]College of Arts and Sciences, Dakota State University, Madison, SD 57042 USA
[5]Animal and Range Sciences Department, North Dakota State University, Fargo, ND 58105
*Corresponding author

Abstract

We conducted studies in native prairie mixed-grass pastures in south-central North Dakota (U.S.A.) during 1989 – 2003 to determine how different grazing intensities affected structural characteristics of vegetation, livestock production and the occurrence and density of grassland birds. Generally, as grazing treatment intensity increased from light to extreme, mean vegetation structural values decreased for visual obstruction readings, tallest plants of grasses, forbs, and shrubs, and litter depth. Nineteen species of non-game birds were detected during 2001 and 2002. Overall breeding bird densities were negatively affected by increasing levels of grazing intensity in mixed-grass prairie. Clay-colored sparrows (*Spizella pallida*), grasshopper sparrows (*Ammodramus savannarum*), and savannah sparrows (*Passrculus sandwichensis*) reached their highest densities in the light and moderate grazing intensity treatments whereas they occurred at very low densities or were absent from extreme grazing intensity treatments. In contrast, densities of chestnut-collared longspurs (*Calcarius ornatus*), horned larks (*Eremophila alpestris*), upland sandpipers (*Bartramia longicauda*), marbled godwits (*Limosa fedoa*), and willets (*Catoptrophorus semipalmatus*) were highest in the heavy and extreme grazing treatment plots. Livestock average daily weight gains and body condition scores decreased directly with increasing grazing intensity. In contrast, average red meat production gains per unit of pasture had a quadratic relationship to stocking rates, increasing with increased grazing intensity (more animals per unit of pasture) until it reached a peak and then declined. Results from this study suggest that management of grassland habitats can be manipulated under specific grazing intensities to provide predictable conditions of nesting habitat for grassland bird species of management concern. Collectively, our results support that stocking rates equal to or nearly equal to our light to moderate grazing intensity treatments would provide habitat for most species of non-game birds nesting in mixed-grass prairies and still enable ranchers to obtain a profit from livestock production.

Keywords: North Dakota, mixed-grass prairies, grazing intensity treatments, non-game birds

Introduction

Historically, grazing by native mammals occurred naturally in most of the northern Great Plains (Lauenroth and others 1994). Native grazers included a mixture of several large ungulates and other, smaller herbivores including rabbits and hares (*Lepus* spp.), prairie dogs (*Cynomys* spp.), ground squirrels (*Spermophilus* spp.) and several species of small rodents and insects. Bison (*Bison bison*) were the dominant grazers in the northern Great Plains prior to European settlement (Shaw 1995) with population estimates ranging from 40 to 60 million (Seton 1929, England and DeVos 1969). Thus, most plant and animal species in the northern Great Plains evolved under the influence of grazing. The presence and the effects of grazing by millions of bison and other animals undoubtedly influenced several natural processes in North American grassland ecosystems (Mack and Thompson 1982, Milchunas and Lauenroth 1993, Knapp and others 1999).

In the 1800s bison herds were replaced with livestock herds across the North American plains (Lauenroth and others 1994). Today's grazing practices differ from the earlier, natural grazing regimes (Wershler 1992), mainly due to the effects of fences, which control the areas being grazed or not grazed at any one time. Between 1870 and 1900 a reduction in quantity and quality of rangeland resources began due to overgrazing and the conversion of rangeland to cropland (Holechek and others 1995). By the early 1900s extensive annual tillage for cropland production was also common in the Great Plains (Lauenroth and others 1994).

A more recent study by Higgins and others (2002) indicated that the conversion of native prairie to cultivated croplands is still continuing at a significant rate. Native tallgrass and mixed-grass prairies that once covered more than 15 million hectares (37 million acres) of North Dakota have been reduced to about 3.9 million hectares (9.6 million acres) (Samson and Knopf 1994). Most of the remaining tracts of unbroken, native grasslands are being managed mainly for livestock and/or wildlife production. In North Dakota, 95% of land use is for agricultural production (Reynolds and others 1994, United States Department of Agriculture 1997) of which three-quarters is for crop production and one-quarter is for livestock production (United States Department of Agriculture 1997).

Recent research suggests that grassland birds are the most rapidly declining guild of endemic bird species in North America (Knopf 1994, Herkert 1995). Fuhlendorf and Engle (2001) found that from 1966 to 1993, 70% of 29 species considered characteristic of North American prairies had experienced population declines. Habitat loss, alteration and fragmentation associated with agricultural land use practices are suggested as factors in these declines (Herkert 1995, Robinson 1996, Igl and Johnson 1997, Peterjohn and Sauer 1999, Bakker and others 2002). Research has shown that cropland provides very few benefits for most species of breeding birds, while grazing lands, when managed properly, can provide multiple benefits for both wildlife populations and livestock producers (Barker and others 1990).

Knopf (1996) suggested that all of the bird species endemic to prairies evolved within a grazed grassland mosaic ranging in gradient from idle areas (Owens and Myres 1973) to excessively grazed areas, which in turn provided a mosaic of vegetation and wildlife habitat types. The importance of a mosaic of habitat types is directly related to the diverse habitat requirements of grassland birds (Rohrbaugh and others 1999, Fuhlendorf and Engle 2001, Bakker and others 2002). However, the effects of grazing on grassland birds can be either positive or negative, depending largely on timing and duration of grazing treatments, type of grazing system, and stocking rates (grazing intensity), and bird species' habitat preferences (Saab and others 1995).

Kirsch and others (1978), Barker and others (1990), Kantrud and Higgins (1992), Kirby and others (1992), Bock and others (1993), Fleischner (1994), Saab and others (1995), and Naugle and others (2000) conducted extensive literature reviews addressing the effects of grazing treatments on grassland nesting birds in the northern Great Plains. Although a majority of the studies reviewed were focused on grassland nesting ducks, several were focused on the effects of grazing on non-game bird species, which is the theme of our study. Few effects of grassland grazing treatments impact birds directly, such as the trampling of eggs in nests (Paine and others 1996). The indirect effects of grazing, including foliage removal (Wiens and Dyer 1975), are known to alter vegetation structural characteristics and floristics significantly, which in turn affects some bird species negatively and some positively, while others exhibit no obvious directional response to grazing (see reviews by Saab and others 1995, Naugle and others 2000).

Grazing, mainly for livestock production, is still an important land use practice and one that impacts millions of hectares of grasslands and their quality on both public and private lands throughout the United States (Bock and others 1993, Fleischner 1994). Generally, grasslands managed with designed rotational grazing systems are more attractive and/or productive for a greater variety of grassland birds than are pastures that are continuously and heavily grazed season-long (Messmer 1985, 1990; Hertel 1987; Grosz 1988; Sedivec 1989, 1994; Barker and others 1990; Sedivec and others 1990; Naugle and others 2000; Buskness and others 2001).

Livestock grazing is important economically for many areas and it also simulates a natural process (Bock and others 1993). Grazing can also be used as a management tool for improving grassland habitat (Holechek 1982). Still, because of the competing interests in economic, social, and conservation issues, grazing is not without controversy (Bock and others 1993). However, research is continuously being conducted on the effects of grazing and researchers are finding many positive relationships between properly managed rangelands and ecosystem processes, especially in places that evolved with grazing (Knapp and others 1999). Currently, with few exceptions, grazing treatments are the most universally available habitat management tools in the northern Great Plains and in many other geographic regions of the world.

However, little information exists relative to vegetation and bird population responses to timing and frequency of grazing treatments in the northern Great Plains (Bowen and Kruse 1993, Kruse and Bowen 1996, Naugle and others 2000). In contrast, several studies and reports have addressed the effects of grazing intensity (stocking rates) including Kantrud (1981), Kantrud and Kologiski (1982, 1983), Messmer (1985, 1990), Hertel (1987), Smoliak (1988), Sedivec (1989, 1994), Barker and others (1990), Sedivec and others (1990), Bowen and Kruse (1993), Saab and others (1995), and Buskness and others (2001). Many researchers adopted vegetation height or residual vegetation characteristics to subjectively partition grazing intensity into low, medium, and high or extreme (over-grazed) categories (see Kirsch and Higgins 1976, Kantrud and Kologiski 1983, Higgins and others 1992); however, they did not provide specific grazing treatment prescriptions that would enable achieving predictable vegetation and avian management goals.

In 1989, the Central Grasslands Research Extension Center (CGREC) staff began conducting research to determine how grazing intensity treatments would affect rangeland hydrology, livestock production, and forage production in south central North Dakota. This study provided a unique chance to also investigate non-game bird responses to grazing intensity treatments in a well-designed experimental area with prescribed treatments. Thus our goal was to determine if there were quantifiable differences in vegetation, livestock, and non-game bird attributes due to the duration and stocking rates of the grazing treatments.

Study Area

All grazed research plots used during this study were located on lands owned and/or managed by the North Dakota State University Central Grasslands Research Extension Center (CGREC). The CGREC is located about 14.4 km (8.9 mi) northwest of Streeter, North Dakota, along the border of Stutsman and Kidder counties. The CGREC occurs on the Missouri Coteau, which is the largest (25,584 km^2) area of hummocky collapsed glacial topography that occurs in North Dakota (Bluemle 2000). The Missouri Coteau is well known for its importance to wildlife, especially breeding birds (Stewart and Kantrud 1972, 1973; Higgins and others 1992). Because much of the land is not tillable, thousands of hectares of native prairie remain in the region. These prairie tracts in combination with numerous prairie pothole wetlands provide critical habitats for numerous species of waterfowl, upland game birds, non-game birds, and shorebirds and grazing lands for livestock.

Vegetation characteristic of upland mixed-grass prairie at CGREC includes a variety of graminoids, forbs, and a few shrub species. Important graminoids include western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love), blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths), Kentucky bluegrass (*Poa pratensis* L.), smooth brome (*Bromus inermis* Leyss.), needle-and-thread grass (*Hesperostipa comata* Trin. and Rupr.), green needlegrass (*Nassella viridula* Trin.), quackgrass (*Elymus repens* (L.) Desv.), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), prairie Junegrass (*Koeleria macrantha* (Lam.) Beauv.), porcupine grass (*Hesperostipa spartea* Trin.), and numerous sedges (*Carex* spp.) (Lura and others 1988, Messmer 1990). Forb components include fringed sage (*Artemisia frigida* Willd.), white sage (*Artemisia ludoviciana* Nutt.), silver-leaf scurf pea (*Pediomelum argophyllum* Pursh), heath aster (*Symphyotrichum ericoides* L.), dotted gay-feather (*Liatris punctata* Hook.), prairie coneflower (*Ratibida columnifera* (Nutt.) Woot. and Standl.), Canada anemone (*Anemone canadensis* L.), and goldenrods (*Solidago* spp.) (Lura and others 1988; Messmer 1990). The most dominant shrub species is western snowberry (*Symphoricarpos occidentalis* Hook.) followed by prairie rose (*Rosa arkansana* Porter), and leadplant (*Amorpha canescens* Pursh) (Lura and others 1988, Messmer 1990).

Climate of the study area is characterized as a cool, subhumid continental type (Omodt and others 1968) with relatively long, cold winters and short, moderately hot summers. Mean annual precipitation in the area is 44.73 cm (17.6 in), 80% of which occurs from April through September (Messmer 1985). Precipitation on the study areas varied between the two years of the bird study. Total precipitation at CGREC was 46.84 cm (18.5 in) during the 2000–2001 crop year (1 Oct.–30 Sept.) and 42.39 cm (16.7 in) during 2001–2002 crop year.

Table 1. Number of heifers, Animal Units (AU), Animal Unit Months (AUM), and Animal Unit Months per hectare (mean ± SD) for grazing intensity treatments at Central Grasslands Research Extension Center, Streeter, ND for 2001 and 2002.

		Year	
	Treatment	2001	2002
Heifers Stocked (Mean/Treatment)	Light	8.3±3.1	7.3±2.1
	Moderate	12.3±0.6	12.7±0.6
	Heavy	14.7±1.5	16.3±2.5
	Extreme	27.0±5.3	26.7±4.7
Animal Units (AU)	Light	6.6±2.3	5.9±1.8
	Moderate	9.6±0.5	10.0±0.3
	Heavy	11.3±1.1	13.0±2.2
	Extreme	20.8±4.5	21.4±4.6
Animal Unit Months (AUM)	Light	25.0±8.6	10.7±3.2
	Moderate	36.6±1.8	18.1±0.5
	Heavy	42.9±4.3	23.3±3.9
	Extreme	78.9±17.2	38.5±8.4
AUM/ha	Light	2.0±0.7	0.8±0.3
	Moderate	2.9±0.1	1.4±0.1
	Heavy	3.4±0.2	1.8±0.3
	Extreme	5.8±0.8	2.9±0.4

Methods

Grazing Intensity Treatments

In the grazing intensity study area, each grazing intensity treatment (i.e., light, moderate, heavy and extreme) averaged about 12 ha (29.6 acre) in size and was randomly replicated three times. Pastures were stocked each grazing season (i.e. the growing season) so that 65%, 50%, 35%, and 20% of the forage produced in an average year was remaining, respectively, in the light, moderate, heavy, and extreme treatments. Livestock entry and removal dates were adjusted yearly with respect to precipitation and plant phenology conditions to keep forage utilization within the desired range for each treatment. During 1989–2002 the length of the grazing season varied from a low of 55 days in 2002 to a high of 181 in 1990. From 1991 to 2002 the mean stocking density ± the standard deviation has been 1.1±0.5 AUM/ha on the light grazing treatment, 2.4±0.7 AUM/ha on the moderate grazing treatment, 4.2±1.1 AUM/ha on the heavy grazing treatment, and 6.8±2.2 AUM/ha on the extreme grazing treatment. Stocking treatments for 2001 and 2002 are presented in Table 1.

Each pasture contained both silty and overflow range sites and monitoring locations were selected on both range sites in each pasture. Silty range sites occurred on nearly level to strongly sloping (1–15%) glacial till uplands on deep, well and moderately well drained soils and were usually higher in the topography than overflow range sites. Overflow range sites occurred on nearly level (1–3% slopes) swales and depressions on residual and glacial uplands and bottomlands on deep, well drained soils that commonly receive additional runoff from the higher silty range sites. Overflow range sites contain greater amounts of tall warm-season graminoids than silty range sites and often greater amounts of western snowberry patches. Six 10 x 120 m (33 x 394 ft) exclosures were used for sampling ungrazed vegetation, three each on silty and overflow sites.

Vegetation Sampling

Forage production and utilization are determined using the cage comparison method (Cook and Stubbendieck 1986). Total herbage was clipped from five caged and ten uncaged 0.25-m^2 plots on each treatment. Herbage samples were separated into three groups (shrubs, forbs and grasses), oven-dried and then weighed to determine the amount of herbaceous production and/or the percentage utilization of the forage. Herbage was clipped from inside caged plots during the peak of the growing season provided an estimate of peak biomass. Differences between biomass in caged and uncaged plots provided an estimate of forage utilization. Data were analyzed using analysis of variance with forage yield as dependent variable and grazing treatment as the independent variable.

Frequency of occurrence of all plant species was monitored annually along transects, each with 50 sampling sites using a nested frame design with 5 x 5 cm (2 x 2 in), 10 x 10 cm (4 x 4 in), and 25 x 25 cm (9.8 x 9.8 in) quadrat frames (Hironaka 1985). Plant density of woody stems, forbs and caespitose grasses were sampled in conjunction with the frequency sampling in the 25 x 25 cm quadrats. Basal cover was sampled using a ten-point frame.

An arcsine transformation was used on the frequency data to convert it from a binomial to a nearly normal distribution. Data were analyzed as a completely randomized design with three replicates per treatment. Because differences in species composition between pastures existed prior to beginning the study, changes due to grazing intensity were determined by subtracting one year from another and analyzing the differences. Analysis of variance was preformed on the frequency and density data sets.

Habitat Structure

Vegetation structure surveys were conducted at 25 stations, spaced 8 m (26 ft) apart along transect lines, paralleling the bird survey transects. Vegetation structure was characterized by measurements taken to the nearest quarter-decimeter on a modified Robel pole (Robel and others 1970, Higgins and Barker 1982). Visual obstruction measurements were taken from each of the four cardinal directions at the point of 100 % visual obstruction of the pole, at a distance of 4 m (13 ft) and a height of 1 m (3.3 ft) (Robel and others 1970). Other vegetation variables included heights of the tallest forb, tallest grass, and tallest woody stem, all of which were measured within a 15 cm (6 in) radius of the pole at each station and were recorded to the nearest quarter-decimeter. Litter depth was measured in millimeters.

Vegetation structure data were collected two times per year for each transect. The first sampling period of each year was conducted before green-up to characterize vegetation structure available to birds as they arrived on the breeding areas. The second sampling period was conducted to characterize the maximum vegetation structure available during the breeding season. Tallest forb, tallest grass, and tallest woody stem variables were measured during the second sampling period. Differences in vegetation structure between grazing treatments were analyzed using t-tests (continuous data) and chi-square tests (categorical).

Livestock Performance

Cattle performance was evaluated by weighing individual animals on a digital platform scale at the beginning and the end of each grazing period. Weights were taken just prior to cattle entry and within four hours following animal transfer to the scale site. Regression analysis (The REG Procedure, SAS 1999) was used to determine the relationships between stocking rates, gain per animal, and gain per hectare.

Bird Surveys

Birds were surveyed in grasslands from sunrise until four hours after sunrise from 30 May to 27 June 2001 and 31 May to 3 July 2002 along 12 systematically placed belt transects (n = 3 for each treatment), of which one was 100 m (328 ft) long and two were 200 m (656 ft) long by 100 m wide totaling 500 m (1600 ft) of transects per treatment plot (Wakeley 1987). Transects were placed > 30 m (98 ft) from field edges and large obstacles (Arnold and Higgins 1986). We noted bird movements to avoid double counting. Transects were walked slowly (ca. 1 km/hr = 0.6 mi/hr) with frequent stops to identify birds by sight or sound. Counts were not conducted when there was heavy to moderate rain, heavy fog, strong winds (> 10 km (6.2 mi) per hour) or extreme temperatures (< 7° or > 24° C) (Mikol 1980). Bird surveys were repeated three times each season and the survey time (early, mid or late a.m.) was rotated for each transect.

Transect bird data were used to determine species occurrence (presence/absence), species richness, and relative bird density (singing males and/or territorial pairs/100 ha). Analysis of variance was used to test for the effects of different grazing treatments on total bird density and the occurrence and density of individual species. Post-hoc tests were used to evaluate the influence of idle and light to extreme grazing on these estimates. All statistical tests were considered significant at $P < 0.05$.

Results

Effects on Forage Production and Utilization

During 1989–2002, peak total above-ground biomass production averaged 1,116 kg/ha (0.5 T/ac) greater on overflow range sites (4,068 kg/ha = 1.8 T/ac) than on silty range sites

(2,952 kg/ha = 1.3 T/ac) in native mixed grass prairie. Grazing resulted in differences among treatments in above-ground biomass at the beginning, middle and end of the growing season on silty and overflow range sites (Table 2). Overall, cattle reduced total above-ground biomass most on the extreme grazing treatment sites in silty and overflow range sites and least on lightly grazed treatments on silty sites and on moderately grazed treatments on overflow sites (see beginning and end of season columns in Table 2); however, biomass difference on overflow sites was similar among light, moderate and heavy treatment plots (Table 2). No year x treatment interaction occurred between treatments on overflow range sites indicating that the effects of grazing intensity on forage production were consistent across all years; however, a year x treatment interaction did occur for silty range sites at the beginning and end of the grazing season.

Table 2. Average above-ground biomass production in kg/ha (lbs/acre) by grazing intensity treatment on silty and overflow range sites from 1992 to 2002.

	Above ground biomass			
Treatment	Beginning of season	Middle of Season	Total Yield	End of season
Silty Sites				
Light	1,581 (1,410) a	3,154 (2,813) a	3,583 (3,196) a	3,401 (3,034) a
Moderate	1,388 (1,238) b	2,793 (2,491) b	3,241 (2,891) b	3,090 (2,756) b
Heavy	1,003 (895) c	2,380 (2,123) c	2,664 (2,376) c	2,546 (2,271) cd
Extreme	809 (722) d	1,908 (1,702) d	2,321 (2,070) d	2,296 (2,048) d
LSD (0.05)	108 (96)	213 (190)	276 (246)	293 (261)
Overflow Sites				
Light	1,295 (1,155) ab	4,389 (3,915) a	4,650 (4,148) a	4,287 (3,824) a
Moderate	1,416 (1,263) a	4,312 (3,846) a	4,845 (4,322) a	4,644 (4,142) a
Heavy	1,413 (1,260) a	4,240 (3,782) a	4,603 (4,106) a	4,562 (4,069) a
Extreme	961 (857) c	2,545 (2,270) c	3,050 (2,721) c	2,973 (2,652) b
LSD (0.05)	131 (117)	396 (353)	409 (365)	434 (387)

[1]Means in the same column followed by the same letter are not significantly different at P = 0.05.

Effects on Plant Species

Of 167 plant species found on the overflow range sites and of 155 plant species found on the silty range sites, collectively, 11 plant species were significantly favored by no or light grazing (four on overflow and eight on silty range sites), 28 species by moderate grazing (11 on overflow and 20 on silty range sites) and 46 species by heavy grazing (35 on overflow and 28 on silty range sites). For the 20 most abundant species found between the 1988 and 2002 sampling periods on overflow range sites, Kentucky bluegrass, smooth brome, stiff goldenrod (*Oligoneuron rigidum* L.), heath aster, and western wheatgrass showed trends of increasing, whereas big bluestem showed trends of decreasing in frequency of occurrence (Table 3). Canada goldenrod (*Solidago canadensis* L.), stiff sunflower (*Helianthus pauciflorus* Nutt.), prairie rose, and western snowberry were most negatively affected by the extreme grazing treatment. Likewise for the same periods on silty range sites, Kentucky bluegrass, heath aster, western yarrow, stiff goldenrod, and fringed sagewart, showed trends of increasing whereas sun sedge (*Carex heliophila* Mack.), blue grama, green needlegrass, and needle-and-thread showed decreasing in frequency of occurrence (Table 4).

Grazing Effects on Vegetation Structure

As grazing intensity increased, vegetation structural values typically decreased, (Table 5). Mean tallest forb in the light and moderate treatments were not different (P > 0.05) and means in the moderate and heavy grazing intensity treatments were not different (P > 0.05). However, tallest forb means were different (P < 0.05) between the light and heavy grazing intensity treatments. The tallest forb mean in the extreme grazing intensity treatments were lower (P < 0.05) than means in all other treatments. Mean values for tallest grass and litter depth were all significantly different (P < 0.05) among all treatments (Table 5). Mean values for visual obstruction readings were significantly lower (P < 0.05) for the heavy and extreme grazing treatments.

Effects on Livestock Productivity and Condition

Long-term average daily gains for 1991–2002 and animal body condition scores for 1994–2002 decreased with increasing grazing intensity (Table 6). The rate at which average daily gain decreased significantly (P < 0.05) with an increase in stocking rate varied greatly from year to year, perhaps due to variation in forage quality or quantity, the effect of weather on the animals, their initial weight, or their potential to gain. When all years were pooled together the variation accounted for by the above relationship between rate of gain and stocking rate was 0.40. When considered on a yearly basis, the R^2 varied between 0.45 and 0.98. In contrast, average gains per unit of pasture (lbs/acre) increased directly with increasing stocking rate during 1991–2002 (Table 6).

Table 3. Mean percent frequency of occurrence values for the 20 most abundant plant species found in 25 x 25 cm quadrats in 1988 (pre-treatment) and 2002 (N = 3/transects/treatment/year, transects consisted of presence or absence in 50 quadrats) on overflow range sites by grazing intensity treatment at the Streeter, ND research site.

Plant Species Common Name (Scientific Name)	Light		Moderate		Heavy		Extreme	
	1988	2002	1988	2002	1988	2002	1988	2002
Kentucky bluegrass (*Poa pratensis* L.)	62	97	73	100	59	98	73	96
buckbrush (*Symphoricarpos occidentalis* Hook.)	55	47	49	49	61	64	65	31
smooth brome (*Bromus inermis* Leyss.)	25	57	31	46	19	71	32	39
stiff sunflower (*Helianthus pauciflorus* Nutt.)	30	49	47	40	65	35	49	6
stiff goldenrod (*Oligoneuron rigidum* L.)	41	46	28	59	9	65	13	55
heath aster (*Symphyotrichum ericoides* L.)	23	39	32	38	35	45	40	48
sun sedge (*Carex heliophila* Mack.)	31	11	34	14	31	24	63	57
cudweed sagewort (*Artemisia ludoviciana* Nutt.)	23	29	22	35	23	40	39	39
western ragweed (*Ambrosia psilostachya* DC.)	16	63	21	39	11	52	1	10
western yarrow (*Achillea millefolium* L.)	8	25	3	27	3	53	3	83
obtuse sedge (*Carex obtusata* Lilj.)	16	17	23	30	26	40	11	35
big bluestem (*Andropogon gerardii* Vitman)	41	21	38	29	17	13	5	12
common dandelion (*Taraxacum officinale* Weber)	0	13	0	33	0	35	0	68
quackgrass (*Elytrigia repens* (L.) Desv.)	19	37	10	23	11	16	14	12
northern bedstraw (*Galium boreale* L.)	6	21	11	28	5	16	16	13
Canada goldenrod (*Solidago canadensis* L.)	19	31	3	18	12	22	3	1
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love)	5	6	5	19	1	23	11	21
prairie rose (*Rosa arkansana* Porter	7	9	10	13	13	3	26	7
wild licorice (*Glycyrrhiza lepidota* Pursh)	13	29	5	4	9	13	0	0
green needlegrass (*Nassella viridula* Trin.)	13	6	3	3	9	5	9	17

Effects on Bird Species

A total of 357 birds were detected in belt transects, representing 17 non-game bird species (for a complete list see Salo 2003). The most commonly occurring species were the clay-colored sparrow (*Spizella pallida*), grasshopper sparrow (*Ammodramus savannarum*), chestnut-collared longspur (*Calcarius ornatus*), and savannah sparrow (*Passrculus sandwichensis*) (Table 7). There was no significant difference between total species richness (number of species for both years) within grazing treatments however, the individual bird species comprising the estimate varied within different grazing intensities.

Generally, as grazing intensity increased, breeding bird densities decreased (Table 8). However, this trend is largely driven by density changes in the two numerically dominant species, clay-colored and grasshopper sparrows. Means in moderate treatments were lower ($P < 0.05$) than means in the light treatment, but all densities were significantly higher ($P < 0.05$) than the heavy and extreme grazing intensity treatments. However, eight of 15 species increased in frequency with increasing grazing intensity while seven of 15 decreased in frequency (Table 7).

Individual birds responded differently to the effects of grazing intensity. Several species exhibited a wide range of tolerance to grazing intensity treatments whereas others occurred only in a single treatment. Brown-headed cowbirds (*Molothrus ater*) and eastern kingbirds (*Tyrannus tyrannus*) had fairly similar densities across the spectrum of grazing intensity treatments (Table 8). Clay-colored sparrow, grasshopper sparrow, and savannah sparrow densities decreased with increased grazing intensity (Table 8). Of these three species, only the grasshopper sparrow occurred in the extreme grazing intensity treatment plots, but in low densities. Chestnut-collared longspur, horned lark (*Eremophila alpestris*), upland sandpiper (*Bartramia longicauda*), willet (*Catoptrophorus semipalmatus*) and marbled godwit (*Limosa fedoa*) were significantly more abundant in the heavy and extreme intensity areas (Table 8). Horned larks, upland sandpipers, willets, and marbled godwits occurred only in the heavy and extreme grazing intensity treatment plots. Common yellowthroats (*Geothlypis trichas*) occurred only in the light grazing intensity treatment transects (Table 8). The Baird's sparrow (*Ammodramus bairdii*) and bobolinks (*Dolichonyx oryzivorus*) occurred only in the moderate grazing intensity treatment.

Discussion

Our findings indicate that controlled treatments of different grazing intensities affected measurable changes in vegetation structure, livestock production and avian populations. Because the treatments were controlled by prescription (design), similar treatment effects and results can also be implemented by private or public grassland managers with fairly predictable results all of which are related to the appli-

Table 4. Mean percent frequency of occurrence values for the 20 most abundant plant species found in 25 x 25 cm quadrats in 1988 and 2002 (N = 3/transects/treatment/year, transects consisted of presence or absence in 50 quadrats) on silty range sites by grazing intensity treatment at the Streeter, ND research site.

Plant Species Common Name (Scientific Name)	Light		Moderate		Heavy		Extreme	
	1988	2002	1988	2002	1988	2002	1988	2002
Kentucky bluegrass (*Poa pratensis* L.)	85	99	93	98	75	92	82	95
sun sedge (*Carex heliophila* Mack.)	72	23	77	28	77	67	76	58
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Love)	30	61	65	58	43	67	58	74
heath aster (*Symphyotrichum ericoides* L.)	45	67	39	55	39	43	35	43
cudweed sagewort (*Artemisia ludoviciana* Nutt.)	31	55	24	45	29	43	12	25
blue grama (*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths)	25	1	42	11	45	36	30	31
green needlegrass (*Nassella viridula* Trin.)	35	9	49	19	30	19	41	11
western yarrow (*Achillea millefolium* L.)	1	9	7	48	3	39	4	64
obtuse sedge (*Carex obtusata* Lilj.)	17	27	15	17	9	44	7	12
stiff goldenrod (*Oligoneuron rigidium* L.)	0	7	1	49	0	39	1	25
fringed sagewort (*Artemisia frigida* Wild.)	3	3	5	18	7	37	3	27
needle-and-thread (*Hesperostipa comata* Trin. and Rupr.)	17	1	15	3	29	5	29	1
common dandelion (*Taraxacum officinale* Weber)	0	3	0	9	0	17	0	49
western ragweed (*Ambrosia psilostachya* DC.)	2	31	3	32	1	3	0	1
Flodman's thistle (*Cirsium flodmanii* (Rydb.) Arthur)	7	23	7	15	4	11	1	5
prairie chickweed (*Cerastium arvense* L.)	0	1	0	13	0	19	0	33
purple milk-vetch (*Astragalus agrestis* Dougl. ex G. Don)	1	13	2	5	3	9	7	24
Wilcox dichanthelium (*Dichanthelium wilcoxianum* (Vassey) Freckmann)	2	2	3	19	3	17	2	13
comandra (*Comandra umbellata* (L.) Nutt.)	8	7	7	17	1	14	0	1
western rock jasmine (*Androsace occidentalis* Pursh)	0	2	0	13	0	12	0	27

cation of a standard measure of grazing treatment (i.e., the Animal Unit Month/ha or AUM/ha) for a set (controlled) period of time.

We determined that average net weight gains per unit area (acre/ha) increased directly with grazing intensity (more animals per unit area); however, individual animal daily rates of gain (ha/head/day) and body condition indices decreased at the same time (Table 6). Our results agree with those reported by Holechek and others (2001). They surmised that red meat productivity per unit area increases up to a point, then decreases as scarcity of forage reduces nutrient intake by livestock, and this is more pronounced in drought years. Thus, maximum gains per animal and per unit area are not concurrently possible. In brief, grasslands grazed at light to moderate rates have greater reserves of standing biomass which benefits grassland birds, shortens the hay feeding period for cattle or permits less adjustment in animal numbers per unit area than would be necessary with heavy or extreme grazing rates. Holechek and others (2001) also showed greater average net monetary returns per animal and per unit area with light or moderate grazing intensity than with heavy stocking rates.

Based on average values of vegetation structure data collected during 2001–2002 (Table 5), we submit that habitat structure attracting a broad array of upland nesting birds in the mixed-grass prairies of the northern Great Plains can best be achieved by applying a moderate stocking rate of about 2.4 + 0.7 AUM/ha. Our highest bird species richness values occurred in heavy and extreme stocking rate pastures but this was due to the presence of killdeers, common nighthawks, marbled godwits, and willets. These species often nest in sites with extremely short vegetation (Kantrud and Higgins 1992). Similarly, livestock production and economic benefits to operators can be best achieved on average with stocking rates ranging from 2.4 + 0.7 (moderate) to 4.2 + 1.1 (heavy) AUM/ha. However, a key to achieving sustainable results at the above prescribed grazing intensities is having treatment prescriptions that also include temporal controls on duration of the grazing that are connected to annual availability of precipitation and soil moisture reserves. For example, our treatments ranged from a low duration of 55 days in 2002 (a very dry year) to a high of 181 days in 1990 (a wet year).

By applying a set number of AUM's per known area-unit of grassland for a set length of time, wildlife and livestock managers should be able to manage for desired characteristics (e.g., height-density, vegetation height, litter depth, animal rates of gain), which in turn will be attractive to certain guilds of non-game bird species and will also enable long-term economic sustainability for private land owners. For example, if a manager wanted to manage rangelands for grassland obligate species like grasshopper sparrows, savannah sparrows and Baird's sparrows, birds that were attracted to relatively taller and denser grassland habitats, our results suggest implementing a moderate grazing regime.

Taking a year like 2002 as an example, a manager could graze 12 to 13 heifers weighing 340 kg for 55 days on 12 ha (29.6 ac), which equates to a grazing intensity of 1.4 AUM/ha during the time period from 23 May through 17 July (Table 1). Our findings illustrate an increasingly negative relationship between vegetation structure values and increasing levels of grazing intensity in mixed-grass prairie in south-central North Dakota, with the bird community responding in species-specific ways. All vegetation height values, visual obstruction values, and litter depth values were reduced in direct relation to more intensive grazing treatments, which, in turn, caused detectable changes in avian species community composition and density among grazing intensity treatments. Overall breeding bird densities and species composition were negatively affected by increasing increments of grazing intensity. However, as grazing intensity increased, the occurrence and density of chestnut-collared longspurs, horned larks, upland sandpipers, willets and marbled godwits also increased. Other studies have found these species prefer heavily grazed areas (Kantrud 1981, Kantrud and Kologiski 1982, 1983, Bock and others 1993). Conversely, clay-colored sparrows, grasshopper sparrows, savannah sparrows, and bobolinks attained higher densities at lower grazing intensities. Although published information is relatively limited on the effects of grazing intensity on breeding birds in northern Great Plains grasslands, other researchers have suggested reasons for a variety of responses exhibited by many species of nongame birds (Kantrud 1981; Kantrud and Kologiski 1982, 1983; Messmer 1990; Bock and others 1993; Herkert and others 1993; Saab and others 1995; Knopf 1996; Kruse and Bowen 1996; Fritcher 1998; Naugle and others 2000). Similarly, our study suggests each species responds to certain elements or characteristics of habitat, and has a threshold for the quantity and quality of structure that it prefers.

Our results have direct application to native mixed-grass prairie in south-central North Dakota but should also have collateral application to grasslands in similar soil-precipitation zones throughout the northern Great Plains of the U. S. and southern Canada. These results indicate that the length of the grazing treatment needs to be adjusted to accommodate drier-than-average growing seasons.

The combination of our findings on vegetation structure and avian use with range and livestock production research results indicates that bird and livestock production can benefit mutually from light to moderate grazing intensity treatments in northern mixed-grass prairies. Our results suggest that management of grassland habitats can be manipulated under specific grazing intensities to provide predictable conditions of nesting habitat for grassland bird species of management concern. Collectively, results from this study indicate that stocking rates equal or nearly equal to our moderately grazed intensity treatments would provide habitat for most species of non-game birds nesting in mixed-grass

Table 5. Mean measures of vegetation characteristics (± 1 standard error) on grazing intensity treatments for visual obstruction, tallest plant, tallest grass, tallest forb, tallest shrub, and litter depth on Central Grasslands Research Extension Center, Streeter, ND averaged for 2001 and 2002.

Mean Vegetation Characteristics	Treatment Light	Moderate	Heavy	Extreme
Visual Obstruction (dm)	5.03b (0.21)	4.58b (0.20)	2.29c (0.18)	0.79d (0.05)
Tallest Grass (dm)	5.29b (0.13)	4.83c (0.14)	2.71d (0.10)	1.75e (0.09)
Tallest Forb (dm)	2.90b (0.09)	2.85bc (0.10)	2.62c (0.08)	1.55d (0.09)
Tallest Shrub (dm)	5.39a (0.20)	5.26a (0.17)	4.13b (0.18)	2.37c (0.19)
Litter Depth (mm)	53.04b (1.35)	45.90c (1.27)	19.78d (0.92)	9.26e (0.40)

[1]Means in the same row with the same letter are not significantly (P >.05) different.

Table 6. Long-term average livestock performance measurements for cattle on the grazing intensity treatment at the Central Grasslands Research Extension Center, Streeter, ND.

Performance Measure	Treatment Light	Moderate	Heavy	Extreme	LSD (P=0.05)	N
Stocking Rate (AUM/ac) [1]	0.446 ± 0.036	0.958 ± 0.048	1.705 ± 0.075	2.753 ± 0.149		36
Stocking Rate (AUM/ha) [1]	1.101 ± 0.090	2.366 ± 0.119	4.212 ± 0.186	6.804 ± 0.368		36
Avg. Daily Gains (lbs/head/day) [1]	1.393 ± 0.056[a3]	1.272 ± 0.052[a]	1.111 ± 0.055[b]	0.773 ± 0.061[c]	0.156	36
Avg. Daily Gains (kg/head/day) [1]	0.632 ± 0.025[a]	0.577 ± 0.024[a]	0.504 ± 0.025[b]	0.351 ± 0.028[c]	0.071	36
Avg. Gains (lbs/acre) [1]	24.4 ± 1.8[c3]	48.5 ± 2.6[b]	77.1 ± 4.8[a]	81.3 ± 7.1[a]	12.7	36
Avg. Gains (kg/ha) [1]	27.4 ± 2.0[c]	54.4 ± 3.0[b]	86.6 ± 5.3[a]	91.3 ± 7.9[a]	14.3	36
Condition Score [2]	5.39 ± 0.06[a]	5.29 ± 0.07[ab]	5.13 ± 0.06[b]	4.78 ± 0.09[c]	0.02	27

[1] Means from 1991–2002.
[2] Means from 1994–2002.
[3] Means (± standard errors) in the same row followed by the same letter are not significantly different (P > 0.05)

Table 7. Percent frequency of occurrence for birds present in belt transect surveys for each grazing intensity treatment at Central Grasslands Research Center, Streeter, ND during the 2001 and 2002 field seasons.

	Percent Frequency of Occurrence			
	Lt	Mod	Hvy	Ex
Clay-colored sparrow *Spizella pallida*	94	89	89	0
Grasshopper sparrow *Ammodramus savannarum*	61	61	17	6
Chestnut-collared longspur *Calcarius ornatus*	17	6	40	67
Savannah sparrow *Passerculus sandwichensis*	40	33	17	0
Red-winged blackbird *Agelaius phoeniceus*	0	11	0	17
Brown-headed cowbird *Molothrus ater*	22	6	22	6
Eastern kingbird *Tyrannus tyrannus*	11	11	6	6
Bobolink *Dolichonyx oryzivorus*	0	6	0	0
Horned lark *Eremophila alpestris*	0	0	11	28
Killdeer *Charadrius vociferous*	0	0	0	33
Common yellowthroat *Geothlypis trichas*	22	0	0	0
Upland sandpiper *Bartramia longicauda*	0	0	0	40
Willet *Catoptrophorus semipalmatus*	0	0	6	22
Western meadowlark *Sturnella neglecta*	6	0	6	11
Baird's sparrow *Ammodramus bairdii*	0	17	0	0
Marbled godwit *Limosa fedoa*	0	0	6	11
Common nighthawk *Chordeiles minor*	0	0	0	17
Species Total in Treatment	8	9	10	12
Total Species	17			

Table 8. Non-game bird densities (males and/or territorial pairs/100 ha) for birds present in belt transect surveys for each grazing intensity treatment at Central Grasslands Research Extension Center, Streeter, ND, during the 2001 and 2002 field seasons.

	Non-game Bird Densities			
	Light	Moderate	Heavy	Extreme
Clay-colored sparrow	152.8a	122.2a	97.2b	0.00
Grasshopper sparrow	58.3a	61.1a	13.9ab	2.8b
Chestnut-collared longspur	8.3a	5.6a	44.4b	61.1b
Savannah sparrow	27.8a	19.4a	11.1a	0.0
Red-winged blackbird	0.0	8.3b	0.0	27.8a
Brown-headed cowbird	13.9	2.8	16.7	2.8
Eastern kingbird	8.3	8.3	5.6	2.8
Bobolink	0.0	5.6b	0.0	0.0
Horned lark	0.0	0.0	11.1	19.4
Killdeer	0.0	0.0	0.0	25.0
Common yellowthroat	13.9	0.0	0.0	0.0
Upland sandpiper	0.0	0.0	0.0	22.2
Willet	0.0	0.0	2.8a	13.9b
Western meadowlark	2.8	0.0	5.6	8.3
Baird's sparrow	0.0	11.1	0.0	0.0
Marbled godwit	0.0	0.0	2.8	8.3
Common nighthawk	0.0	0.0	0.0	8.3
Total Density[1]	286.1a	244.4b	211.2c	202.7c

[1]Means in the same row with the same letter are not significantly different (P > 0.05)

prairies, except those species which prefer extremely short vegetation for nesting, and still enable ranchers to obtain a profit from livestock production. Studies similar to this one should be conducted in other grassland regions of North America to accommodate other species and grassland habitat types.

Acknowledgments

We would like to thank Drs. Lester Flake and James Rice for their critical reviews and Dr. Timothy Wittig for his help with statistical analysis. We also thank Dennis Whitted and Jay Volk for their help with vegetation sampling. Ed Meendering and Natoma Buskness of the U.S. Fish and Wildlife Service assisted with idle study plot selections. Larry Tidemann provided funding for this project through the U.S. Department of Agriculture's Renewable Resource Extension Act. Equipment and partial funding for the project was provided by the South Dakota Cooperative Fish and Wildlife Research Unit in cooperation with North Dakota State University, South Dakota State University, the U.S. Geological Survey, South Dakota Game, Fish and Parks Department, the U.S. Fish and Wildlife Service, and the Wildlife Management Institute.

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