

Grassland Wildlife Habitat Management: A Guide for Livestock Producers of the Northern Plains



North Dakota State University
Dickinson Research Extension Center
2020

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Llewellyn L. Manske PhD
Scientist of Rangeland Research

Project Assistant
Sheri A. Schneider

Cover Photograph
Male Prairie Chicken
by Al Smith

North Dakota State University
Dickinson Research Extension Center
1041 State Avenue
Dickinson, North Dakota 58601

Tel. (701) 456-1118
Fax. (701) 456-1199

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Preface

This research project originally was proposed to determine the prairie grouse habitat use during their annual phenological life cycle. This study started as a wildlife Masters project from St. Cloud State University designed with help from Dr. Al Grewe and Leo Kirsch. Data collection started in the Sandhills region during the fall of 1974. North Dakota State University was conducting a grassland management project in the same region funded by the Sheyenne Valley Grazing Association. I was hired in February 1975 as a technician to help NDSU graduate students collect their data and I could collect my project data when they did not need my assistance. The North Dakota Game and Fish Department was conducting spring prairie grouse census in the Sandhills region. I was asked to collect the spring census data. I agreed. That continued from the spring of 1975 through the spring of 1980. In July 1975, I was accepted as a PhD graduate student in range management at NDSU and started another project that evaluated the effects of 36 different grazing systems on the grassland vegetation and to determine the compatibility of prairie wildlife habitat management and livestock production in the Northern Plains.

The pastures that had two grazing periods per growing season had increasing basal cover of native grasses, increasing herbage biomass production, and decreasing Kentucky bluegrass density. As additional allotments implemented two times over in more pastures, the prairie grouse male population increased. The herbage biomass data was showing that there was sometimes greater biomass produced on the grazed treatment with two grazing periods than was being produced on the ungrazed areas. There was no biological reason known at that time to explain why these improvements in grazed herbage should occur. I also could not explain why the grass species improved nor why the prairie grouse population was increasing. My graduate committee suggested that I put nothing in the 1980 PhD dissertation that did not have a plausible biological explanation. So I had to wait to find a way to explain the improved phenomenon. Which would become the underlying goal for all of my future research to come.

Fortuitously, the basic science information that I needed to explain why the vegetation and prairie grouse were responding positively in pastures that were grazed two times per growing season was being published. Coleman et al. (1983) explained the symbiotic rhizosphere microorganisms. McNaughton (1983) explained compensatory plant growth from grazing defoliation. Richards et al. (1985, 1988) explained regrowth and tillering following defoliation. Briske and Richards (1994, 1995) explained grass plant physiological processes to compensate for defoliation. During the period from late 1970's through the 1990's numerous scientists discovered the basic processes and mechanisms that work in grassland ecosystems. However, these basic scientists did not do the applied research to show how to make the processes and mechanisms work in grassland ecosystems. That applied research took me 20 years to figure out how to manage grasslands to activate the ecosystem processes and grass plant mechanisms with partial grazing defoliation. Then it took another 20 years to document that the ecosystem processes and grass mechanisms were activated and improving. The twice-over rotation grazing strategy was scientifically reviewed and published as a book chapter in 2018 by Burleigh Dodds Science Publishing, Cambridge, UK. Since then, I have been summarizing my research findings as it relates to the new basic and applied research data. This grassland wildlife habitat management report will be completed with the biological explanations in 2020, 46 years after it was started.

Complexity of Effects from Grazing Practices on Prairie Vegetation and Prairie Wildlife Habitat

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1189

Grazing effects grassland plants differently depending on season of use, plant phenological growth stage, intensity of defoliation, and duration of grazing periods. These differential responses of the grassland vegetation to grazing treatments has consequential affects on prairie wildlife populations that depend on grassland plants for their habitat. Variances in the affects on grassland plants and prairie wildlife habitat by various types of grazing treatments were not well understood at the start of this study. The relationships of partial defoliation by grazing, prairie grass growth, and prairie wildlife habitat are so intricately complex that they are perplexing which makes this ecological problem extremely intriguing.

An ideal place to initiate the comprehension of the effects of grazing on prairie vegetation and prairie wildlife habitat is the Sandhills region of southeastern North Dakota. This region is an island with 130,560 acres (52,837 ha) of native vegetation surrounded by intensively managed cropland. This region consists of 31.6% mixed grass prairie, 23.8% tall grass prairie, 13.9% sedge meadow, 13.8% forest and woodland, and 17.0% cropland with tree shelterbelts. The Sheyenne Valley Grazing Association has records of the grazing management practices used since 1940 and the North Dakota Game and Fish Department has records of the prairie grouse male census data since 1961. Manske (1981) conducted the prairie grouse census during 1975 to 1981. Synchronization of these two data sets, as suggested by Kobriger et al. (1987), can yield important generalized relationships between grazing practices and prairie grouse population increases or declines.

Critique

Prairie chicken are not a native bird in North Dakota. There were no prairie chicken in North Dakota prior to 1870 (Johnson 1964). Prairie chicken moved north and west following homesteader's agriculture (Partch 1973, Flake et al. 2010). Prairie chicken most likely moved into the Sandhills region during the early settlement period

sometime in the 1870's or 1880's. The combination of tallgrass prairie with 5 or 10 acres of cropland on each quarter section of land with wheat or oat shocked in the field to dry and cob corn stored in slated cribs was favorable for the prairie chicken population to increase. The population in the sandhills region was large enough to be commercially hunted between 1900 and the 1920's. The Sandhills was also a popular location for nonresident sport hunting during the early 1900's. There is no record that sharptailed grouse inhabited the region until 1961. A considerable decline in the prairie chicken population occurred during the late 1920's and 1930's.

During 1937 to 1939 the federal government repurchased 52% of the sandhills region as submarginal homestead land which was authorized by the Land Utilization Project and Resettlement Plan of 1935 and the Bankhead-Jones Farm Tenant Act of 1937 and placed administration under the USDA Soil Conservation Service (table 1). These lands were designated in the takings for grazing use and for economic development from livestock agriculture. The land was divided into 10 large common blocks and from 1940 to 1954 they were grazed seasonlong for 8 months. The sedge meadows were mowed for hay that was fed late season in the pasture. During the 1940's and 1950's, the prairie chicken population was extremely low with birds seen only infrequently by local ranchers (from personal communication). In 1954, the administration was transferred to the USDA Forest Service. The 10 common grazing blocks were divided into 56 allotments. During 1955 to 1967, the 56 allotments were grazed seasonlong for 6 months from mid May to mid November. The sedge meadows were mowed for hay, moved, and fed on private land.

The first prairie grouse census was conducted in 1961 (table 1, figure 1). Two census routes covered 46 linear miles and 88 square miles. Six booming grounds were heard. Two grounds were counted with 5 male prairie chicken and 1 hybrid. No dancing grounds were located but a few sharptailed grouse were observed.

In 1962, one census route covered 44 square miles during which two new booming grounds were located, three grounds were counted with 9 male prairie chicken and three known grounds had no activity.

In 1963 a new census route was run and one new booming ground and one dancing ground were heard. Four known grounds were heard and one ground was counted with 9 male prairie chicken. In 1965, no census routes were run. One ground was counted with 4 male prairie chicken. In 1966, two grounds were visited, one ground had 3 male prairie chicken and the other ground was not active. During 1964 and 1967 no prairie grouse census work was conducted because of inclement weather. During the period of 1961 to 1967, 9 booming grounds and 1 dancing ground were located. The prairie grouse population remained low with probably not more than 23 male prairie chicken and 5 or 6 male sharptailed grouse. All of the public land allotments were being grazed seasonlong for 6 months.

Cross fencing of some allotments began in 1967. In 1968 to 1970, 22 allotments, 39% of the land, had 2, 3, or 4 multiple pastures managed by rotation grazing with one period each per year. 34 allotments, 61% of the land, were grazed seasonlong for 6 months. Also during 1968 to 1978, permittees burned 5,000 acres of sedge meadow per year.

During 1968, three prairie grouse grounds were censused, 2 were not active, and at least one prairie chicken was heard on the third ground. In 1969, two prairie grouse grounds were censused, 1 was not active and the other ground had moved and had 7 male prairie chicken. The spring of 1970 was windy during April and May and only 2 grounds were counted that had a total of 3 male prairie chicken and 11 male sharptailed grouse.

During 1971 to 1973, 18 pastures in 15 allotments had 2 grazing periods per year with one pasture deferred. 20 allotments had multiple pastures grazed 1 time per year. 21 allotments were grazed seasonlong for 6 months.

In 1971, 8 grounds were counted, one was not active, 3 booming grounds had only prairie chicken with 14 males, 3 dancing grounds were occupied with 25 male sharptailed grouse, 1 ground was mixed with 5 male prairie chicken and 4 male sharptailed grouse. In 1972, 14 known grounds and 3 new grounds were counted, 2 were not active, 8 booming grounds had 38 male prairie chicken, 3 dancing grounds had 30 male sharptailed grouse and

3 hybrids, 4 grounds were mixed with 30 male prairie chickens, 26 male sharptailed grouse, and 9 hybrids. In 1973, 17 known grounds and 3 new grounds were counted. Three grounds were not active, 8 booming grounds had 54 male prairie chicken and 1 hybrid, 3 dancing grounds had 18 male sharptailed grouse and 1 hybrid, 6 grounds were mixed with 35 male prairie chicken, 34 male sharptailed grouse, and 5 hybrids.

In 1970, there were 10 display grounds known. In 1973, the number of known active display grounds increased to 20, the number of active male prairie chicken jump up to 89, and the number of active male sharptailed grouse jump up to 52, and there were 7 hybrids. This large increase in prairie grouse corresponded with the initiation of 18 pastures grazed twice-over in a growing season.

During 1974 to 1978, the number of allotments grazed seasonlong was decreased to 15. The number of allotments managed with multiple pastures grazed only one time per year was decreased to 11. 16 allotments were managed with multiple pastures grazed 2 times per year with one pasture deferred. For the first time, 14 allotments were managed with all of their multiple pastures grazed 2 times per year.

In 1974, 6 new display grounds were located. 7 of the known grounds were not censused. One ground was not active. Ten booming grounds had 57 male prairie chicken. Four dancing grounds had 30 male sharptailed grouse and 2 hybrids. Four grounds were mixed with 21 male prairie chicken and 18 male sharptailed grouse.

In 1975, 19 booming grounds had 116 male prairie chicken, 3 male sharptailed grouse, and 7 hybrids, 5 dancing grounds had 46 male sharptailed grouse, 4 male prairie chicken, and 4 hybrids, and 5 mixed grounds had 23 male prairie chicken, 4 sharptailed grouse, and 9 hybrids.

In 1976, 18 booming grounds had 122 male prairie chicken and 12 hybrid, 5 dancing grounds had 23 male sharptailed grouse and 1 male prairie chicken, and 6 mixed grounds had 27 male prairie chicken, 7 male sharptailed grouse, and 3 hybrids.

In 1977, 21 booming grounds had 160 male prairie chicken, 1 male sharptailed grouse, and 3 hybrids, 6 dancing grounds had 35 male sharptailed grouse, and 5 mixed grounds had 29 male prairie chicken, 15 male sharptailed grouse, and 3 hybrids.

In 1978, 17 booming grounds had 172 male prairie chicken and 3 hybrids, 4 dancing grounds had 25 male sharptailed grouse and 1 hybrid, and 7 mixed grounds had 25 male prairie chicken, 14 male sharptailed grouse, and 2 hybrids.

In 1979, 29 booming grounds had 280 male prairie chicken, 7 male sharptailed grouse, and 9 hybrids, 12 dancing grounds had 104 male sharptailed grouse, 1 male prairie chicken, and 4 hybrids, and 11 mixed grounds had 57 male prairie chicken, 45 male sharptailed grouse, and 5 hybrids.

In 1980, 31 booming grounds had 352 male prairie chicken, 15 male sharptailed grouse, and 10 hybrids, 12 dancing grounds had 110 male sharptailed grouse, 9 male prairie chicken, and 7 hybrids, and 11 mixed grounds had 50 male prairie chicken, and 65 male sharptailed grouse.

During the period between 1973 and 1980, the amount of public land that was managed with two times over in one growing season increased from 10% to a peak of 54% in 1978. In 1973, there were 20 active display grounds with 89 male prairie chicken, 52 male sharptailed grouse, and 7 hybrid. The prairie grouse population increased greatly each year until the all time peak in 1980 that had 54 active display grounds with 411 male prairie chicken, 190 male sharptailed grouse, and 17 hybrids.

During 1979 and 1980 the grazing management was drastically changed by the new ranger with 70% of the public acreage grazed one time per year and one pasture of most allotments were deferred until late season. No allotments had all of the pastures grazed two times per year. 6 allotments had some pastures (12% of the land) that were grazed two time per year, other pastures were grazed one time per year, and one pasture was deferred to late season. And 14 allotments were grazed seasonlong for 6 months. Also unfortunately during 1978 to 1987, the forest service burned less than 500 acres of sedge meadow per year.

During 1981 to 1987 the grazing management was generally highly changeable. The pastures grazed two times per year decreased to zero. Most allotments had multiple pastures grazed one time per year with one deferred to late season. 4 allotments were managed with rapid rotation. During this period, the prairie grouse population had wide irregular fluctuations with declining trend.

Discussion

It should be possible to assume that during periods of prairie grouse population increases or decreases, the quality and quantity of favorable wildlife habitat had correspondingly increased or decreased as a result of the beneficial or detrimental effects from the recently implemented grazing management practice on the grassland vegetation. However, these suppositions do not let us know what the effects on the grassland vegetation are from the various types of grazing management practices.

The synchronized schedule of the grazing management practices used with the male prairie grouse census data has revealed that 28 years of seasonlong grazing for 8 months and 6 months does not provide wildlife habitat at an adequate level of quality to much more than maintain a low population of prairie grouse. The increase in prairie grouse population started when multiple pastures were grazed one time per year and some pastures were deferred. The population increase grew faster when the number of pastures grazed two times per year were increased. The peak prairie grouse population was reached when 54% of the public land was grazed two times over. With a major change in grazing management back to multiple pastures grazed one time per year and one pasture deferred, the prairie grouse population plummeted. These management caused problems continues with a period of inconsistent changes in management practices that caused the prairie grouse population to become unstable with irregular fluctuations in a downward trend.

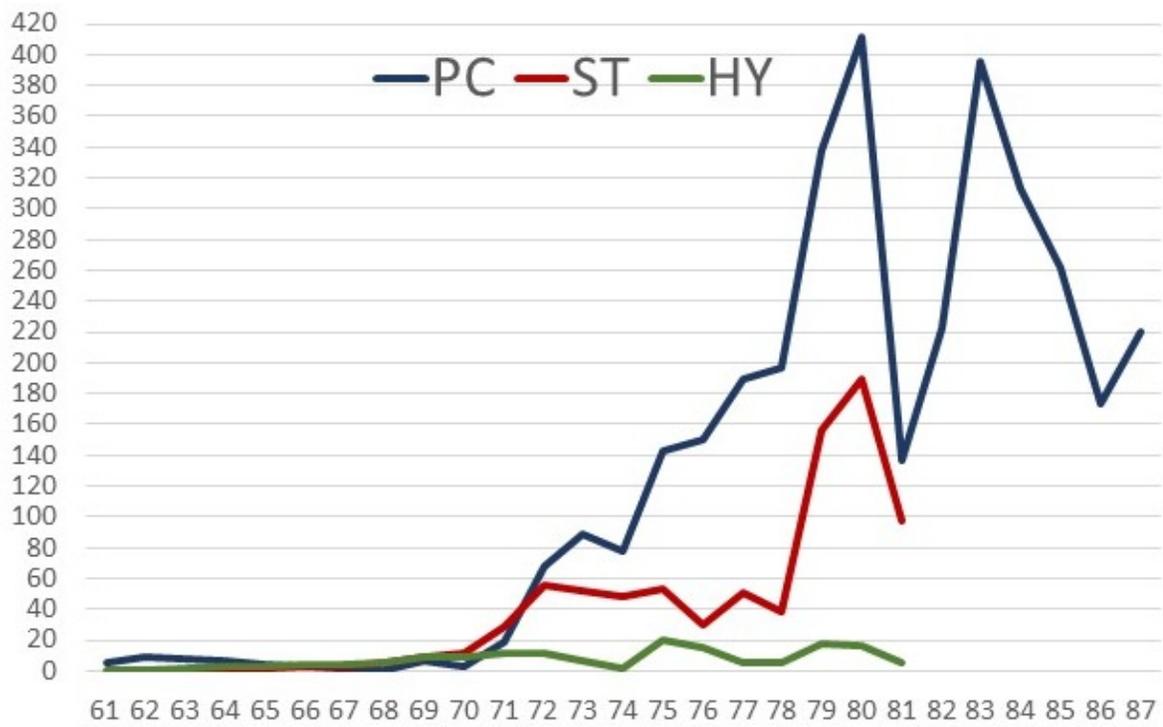
Prairie vegetation does not change instantaneously to changes in grazing management practices nor does prairie wildlife habitat change instantaneously. Improvement or degradation of grassland community productivity and prairie wildlife habitat quality and the length of time required for substantial changes depends on how partial defoliation by grazing at different growth stages and intensities affects grass growth mechanisms and ecosystem biogeochemical processes. Understanding how various grazing management practices effect grassland vegetation and prairie wildlife habitat required additional research.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the table and figure.

Table 1. Synchronization of prairie grouse male census data with grazing management practices used records.

Years	Prairie Grouse			Grazing management practices used
	PC	ST	Hy	
1937	Blank spaces are unknown			1937-1939 Submarginal homestead land repurchased
				1940-1954 10 common blocks grazed 8 month seasonlong
				1955-1967 56 allotments grazed 6 month seasonlong
1961	5		1	
1962	9			
1963	9	?		
1964	-			
1965	4			
1966	3			
1967	-			
1968	1			1968-1970 34 allotments, 61% land, grazed 6 months seasonlong
1969	7	0	0	22 allotments, 39% land, multiple pasture grazed 1 time
1970	3	11	0	
1971	19	29	0	1971-1973 21 allotments, grazed 6 month seasonlong
1972	68	56	12	20 allotments, multiple pastures grazed 1 time
1973	89	52	7	15 allotments, 3 pastures 2 grazed 2 times, 1 deferred
1974	78	48	2	1974-1978 15 allotments, 8% land, grazed 6 month seasonlong
1975	143	53	20	11 allotments, 23% land, multiple pasture grazed 1 time
1976	150	30	15	16 allotments, 43% land, multiple pastures grazed 2 times, 1 deferred
1977	189	51	6	14 allotments, 26% land, multiple pastures grazed 2 times
1978	197	39	6	
1979	338	156	18	1979-1980 14 allotments, 10% land, grazed 6 months seasonlong
1980	411	190	17	36 allotments, 70% land, multiple pastures grazed 1 time
1981	137	97	6	6 allotments, 20% land, multiple pastures grazed 2 times, 1 deferred
1982	223			1981-1987 Multiple pastures grazed 1 time, 1 deferred, increased
1983	396			Pastures grazed twice-over reduced to zero
1984	313			4 allotments managed by rapid rotation
1985	262			
1986	173			
1987	220			
1988	-			
1989	-			
1990	206	57		
1991	163	87		



Male Prairie Grouse

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Effects from Grazing Treatments on Grassland Vegetation and Prairie Wildlife Habitat

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1190

Various types of grazing treatments effect grassland vegetation differently, because variations in the percent removal of the standing herbage biomass at different phenological growth stages of grass lead tillers causes huge differences in the responses of the internal grass growth mechanisms and the ecosystem biogeochemical processes, resulting in increases or decreases of basal cover and herbage biomass of grass species categories, producing variations in the quality of prairie wildlife habitat. The effects from 36 grazing treatments, with at least two replicates of each type, on the aboveground components of grassland vegetation and the resultant changes to prairie wildlife habitat were studied for six field seasons in the Hummocky Sandhills Habitat Association of the Sandhills region of southeastern North Dakota.

Procedures

Grazing treatment effects on the aboveground components of grassland vegetation were monitored by the paired plot method. Two similar plots of representative sites with equal quantities of upland, midland, and lowland communities were established; one plot was exposed to the grazing treatment and the other plot excluded from grazing by a barbed wire enclosure.

Aboveground herbage biomass productivity was sampled by hand clipping to ground level in five $\frac{1}{4}$ m² quadrats on each of the three plant communities in each paired plot during five biweekly periods from June through August. Vegetation was separated in the field into six biotype categories placed in separate labeled paper bags that were oven dried and weighed.

Plant species composition was determined annually during July and August. Graminoid basal cover was sampled by the ten pin point frame with 3000 points per sample site. Forbs were sampled with 25 0.1 m² quadrats, and shrubs were sampled with 25 1.0 m² quadrats by counting the number of each species rooted in each quatrat. These methods were described by Cook and Stubbendieck (1986).

Concealment cover quality of prairie wildlife habitat were evaluated by visual obstruction determined with the height-density pole developed by Robel et al. (1970a) and modified by Kirsch (1974). Twenty five pole sets with an interval of 12 paces were made in homogenous vegetation along transects of 275 meters (900 feet) long. Four readings at a height of 1.0 meter and a distance of 4.0 meters (13 feet) were made at each pole set for the 0% and 100% visual obstruction measurements (VOM) to the nearest 0.5 decimeter (2 inches) at the four major compass directions.

Results and Discussion

The herbage biomass (tables 1, 2, and 3) and basal cover (tables 4, 5, and 6) from three grazing management treatments of seasonlong, deferred, and twice-over were compared for three years. The second growing season experienced great water deficiency conditions. The seasonlong treatment had been unchanged since 1954. The data collected represents the vegetation that remains following grazing. The deferred treatment was grazed during the late season after mid September. The data collected represents the early season ungrazed vegetation. The twice-over treatment had recently been initiated a year or two before. The data collected represents the vegetation that remains following grazing.

Both the seasonlong and deferred treatments were beneficial for the increase of the naturalized species of Kentucky bluegrass on the upland and midland communities (tables 1 and 4). The herbage biomass of native mid and short grasses on the upland, and tall, mid, and short grasses on the midland (table 1), and the basal cover of native cool and warm season grasses on the upland and midland communities (table 4) were similar on the seasonlong and deferred treatments. The grazed vegetation on the seasonlong treatment had several data points at greater levels than that on the ungrazed deferred treatment (tables 1 and 4).

The twice-over treatment reduced the herbage biomass (tables 2 and 3) and basal cover (tables 5 and 6) of the naturalized species of Kentucky bluegrass on the upland and midland communities compared to the seasonlong and deferred treatments. The twice-over treatment increased the herbage biomass of native mid and short grasses on the upland, and tall, mid, and short grasses on the midland (tables 2 and 3), and increased the basal cover of the warm season grasses on the upland and midland communities (tables 5 and 6) compared to the seasonlong and deferred treatments.

It has collectively been assumed that all grazing treatments reduce herbage biomass, according to the observations of the effects of grazing managed by seasonlong treatments that reduce the quantity of herbage biomass incrementally as the grazing season progresses. Problematically, on the Sandhills region, the highly productive zone of the switchgrass community on the foot slope and the sedge meadow community on the toe slope grow very rapidly, reaching senescence, and depositing silicon crystals in grass leaf epidermis during the early portion of the grazing season. Cattle generally stop grazing these areas in mid and late season and transfer grazing pressure to the upland and midland communities resulting in very low utilization on the lowland with greater utilization on the upland and midland communities.

An unexpected result was documented during this study. Pastures that were grazed 2, 3, and 4 times over in one growing season produced greater herbage biomass during some data collection periods on the grazed area than that produced on the ungrazed area (table 7). The one pasture seasonlong produced greater herbage biomass on the grazed area of the midland site 13% of the sample periods. The three pasture system with one pasture deferred and 2 pastures grazed 2 times over produced greater herbage biomass on the grazed area of the midland site 20% of the sample periods. The two pasture switchback system with each pasture grazed 3 or 4 times over produced greater herbage biomass on the grazed area of the upland and midland sites 30% of the sample periods. The three pasture twice-over on each pasture produced greater herbage biomass on the grazed area of the upland and midland sites 32% of the sample periods.

During the time this data was collected, there was no known biological explanation for the production of greater herbage biomass on the grazed area compared to that produced on the ungrazed area. A committee of knowledgeable scientists concluded

that the most logical cause for these research results was sampling error. The data had been collected according to protocol. It required 20 years of research to find that partial defoliation that removes 25% to 33% of the aboveground foliage of lead tillers at vegetative phenological growth stages between the 3.5 new leaf stage and the flower stage can activate the internal grass physiological growth mechanisms and the ecological biogeochemical processes after the rhizosphere microorganism biomass has been increased to a level that can mineralize nitrogen at 100 lbs/ac (112 kg/ha). These mechanisms and processes are able to produce replacement herbage biomass at 140% of the quantity removed by grazing, thus increasing herbage biomass production on the grazed area above that produced on the ungrazed area, as described by Manske (2018) in *Restoring Degraded Grasslands*, @ <https://hdl.handle.net/10365/28801>.

Basal cover of biotype categories and major graminoid species were further analyzed by changes between pre- and post treatment.

The seasonlong treatment caused the total basal cover to have wide annual changes, however, over the study period the basal cover of Kentucky bluegrass increased significantly and the basal cover of native cool and warm season grasses tended to decrease.

The two pasture switchback system caused significant reductions in basal cover of switchgrass and warm season grasses and caused trends of reduced basal cover of cool season grasses and upland sedges.

The deferred pasture practice caused significant increases in basal cover of Kentucky bluegrass, caused significant reductions in basal cover of switchgrass and warm season grasses, and caused trends of reduced basal cover of cool season grasses and upland sedges.

The twice-over rotation strategy caused significant increases in basal cover of switchgrass, lowland sedge, and the total basal cover, and caused trends of increased basal cover of warm and cool season grasses and upland sedges.

The ability of grassland vegetation to obstruct vision of prairie grouse was considered to be a very important factor in the evaluation of habitat quality (Hamerstrom et al. 1957, Robel et al. 1970b). Readings of 100% visual obstruction at 1.5 decimeters (5.9 inches) was considered to be the

minimum level for good concealment cover used as nest, roost, and escape sites by prairie grouse (Manske 1981, Higgins and Barker 1982). The switchgrass portion of the midland grassland community located on the foot slope was determined to be the primary prairie grouse concealment cover on the Sandhills region (Manske 1981).

The visual obstruction measurements (VOM) of the switchgrass community was used to evaluate the ability of grazing treatments to provide prairie grouse concealment habitat at adequate quality (table 8). The spring time period readings from the grazing treatments indicate the amount of concealment cover available for nesting hens. The fall time period readings from the grazing treatments indicate the amount of roosting and escape cover for prairie grouse during the fall and winter. The difference between the fall readings and the spring readings should give an idea of the quality of the habitat lost by snow pack and wind.

All of the grazing treatments did provide some habitat above the minimum 1.5 dm. The seasonlong treatment provided the least quantity of habitat with the mean 100% VOM at 1.5 dm and 55% of readings at or above 1.5 dm. The two pasture switchback treatment and the three pasture deferred treatment were not much different from each other with the mean 100% VOM at 1.7 dm for both. The quantity of readings at or above 1.5 dm was 59% on the two pasture switchback and was 66% on the three pasture deferred treatments. The three pasture twice-over on all had the greatest mean 100% VOM at 2.0 dm and had 76% of the readings at or above 1.5 dm.

Quality of prairie grouse concealment cover habitat can be improved by implementation of grazing management strategies that are designed to increase the rhizosphere microorganism biomass in order to mineralize 100 lbs/ac of available nitrogen, and also that stimulate the four major grass physiological growth mechanisms and the ecosystem biogeochemical processes (Manske 2018).

The standard go to wildlife habitat management treatment of undisturbed grassland is not a biologically viable treatment of grasslands. Grasslands require grazing graminivores. Removal of grazing graminivores does not permit a grassland to move to climax. Grasslands without grazing graminivores decreases in native grasses, increase in nonnative invader plants and increase in woody species (Manske 2013, 2018).

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.

Table 1. Mean herbage biomass (lbs/ac) for the upland, midland, and lowland rangeland sites managed by deferred and seasonlong grazing treatments.

Range Site Plants	Deferred			Seasonlong		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Upland						
Naturalized Grass	56.29	2.43	112.46	48.10	26.41	247.91
Mid Grass	167.27	65.79	256.90	125.88	124.02	211.08
Short Grass	266.31	159.85	261.89	181.11	132.30	278.87
Native Forbs	363.65	149.57	340.82	161.85	318.55	398.50
Annual Forbs	0.0	99.19	4.57	0.0	22.41	11.70
Total Biomass	853.52	476.83	976.64	516.94	623.69	1148.06
Midland						
Naturalized Grass	61.23	38.96	194.53	62.51	30.54	283.44
Tall Grass	227.21	137.11	341.53	76.64	83.63	238.34
Mid Grass	344.10	102.33	175.83	284.30	279.02	102.62
Short Grass	271.17	362.94	502.09	112.46	407.61	296.86
Native Forbs	454.71	51.95	234.05	159.99	104.19	280.87
Annual Forbs	0.0	1.86	27.69	0.0	21.27	10.71
Total Biomass	1358.42	695.15	1475.72	695.90	926.26	1212.84
Lowland						
Graminoids	2098.98	842.62	2200.89	1541.95	1783.86	1926.86
Forbs	91.20	427.16	436.44	115.60	50.24	180.40
Total Biomass	2190.18	1269.78	2637.33	1657.55	1834.10	2107.26

Bold values are greater on the seasonlong treatment than on the deferred treatment.

Table 2. Mean herbage biomass (lbs/ac) for the upland, midland, and lowland rangeland sites managed by seasonlong and two times over grazing treatments.

Range Site Plants	Seasonlong			Two Times Over		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Upland						
Naturalized Grass	48.10	26.41	247.91	56.41	12.31	14.99
Mid Grass	125.88	124.02	211.08	122.35	170.73	247.61
Short Grass	181.11	132.30	278.87	346.96	262.75	366.43
Native Forbs	161.85	318.55	398.50	222.78	449.95	413.26
Annual Forbs	0.0	22.41	11.70	0.20	75.84	45.94
Total Biomass	516.94	623.69	1148.06	748.70	971.58	1088.23
Midland						
Naturalized Grass	62.51	30.54	283.44	69.60	22.91	96.66
Tall Grass	76.64	83.63	238.34	360.35	310.92	308.83
Mid Grass	284.30	279.02	102.62	360.41	292.96	182.66
Short Grass	112.46	407.61	296.86	311.91	383.37	276.07
Native Forbs	159.99	104.19	280.87	156.03	259.67	307.50
Annual Forbs	0.0	21.27	10.71	0.14	5.33	12.69
Total Biomass	695.90	926.25	1212.84	1258.44	1275.16	1184.41
Lowland						
Graminoids	1541.95	1783.86	1926.86	1194.08	1373.19	1400.91
Forbs	115.60	50.24	180.40	142.71	212.44	282.61
Total Biomass	1657.55	1834.10	2107.26	1336.79	1585.63	1683.51

Bold values are greater on the two times over treatment than on the seasonlong treatment.

Table 3. Mean herbage biomass (lbs/ac) for the upland, midland, and lowland rangeland sites managed by deferred and two times over grazing treatments.

Range Site Plants	Deferred			Two Times Over		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Upland						
Naturalized Grass	56.29	2.43	112.46	56.41	12.31	14.99
Mid Grass	167.27	65.79	256.90	122.35	170.73	247.61
Short Grass	266.31	159.85	261.89	346.96	262.75	366.43
Native Forbs	363.65	149.57	340.82	222.78	449.95	413.26
Annual Forbs	0.0	99.19	4.57	0.20	75.84	45.94
Total Biomass	853.52	476.83	976.64	748.70	971.58	1088.23
Midland						
Naturalized Grass	61.23	38.96	194.53	69.60	22.91	96.66
Tall Grass	227.21	137.11	341.53	360.35	310.92	308.33
Mid Grass	344.10	102.33	175.83	360.41	292.96	182.66
Short Grass	271.17	362.94	502.09	311.91	383.37	276.07
Native Forbs	454.71	51.95	234.05	156.03	259.67	307.50
Annual Forbs	0.0	1.86	27.69	0.14	5.33	12.69
Total Biomass	1358.42	695.15	1475.72	1258.44	1275.16	1184.41
Lowland						
Graminoids	2098.98	842.62	2200.89	1194.08	1373.19	1400.91
Forbs	91.20	427.16	436.44	142.71	212.44	282.60
Total Biomass	2190.18	1269.78	2637.33	1336.79	1585.63	1683.51

Bold values are greater on the two times over treatment than on the deferred treatment.

Table 4. Mean basal cover (%) for the upland, midland, and lowland rangeland sites managed by deferred and seasonlong grazing treatments.

Range Site Plants	Deferred			Seasonlong		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Upland						
Naturalized Grass	12.8	0.0	6.8	13.8	5.0	13.6
Cool Season Grass	8.2	0.2	5.6	4.8	2.0	1.8
Warm Season Grass	27.4	26.0	21.8	30.0	11.2	19.8
Upland Sedges	15.4	3.8	3.8	14.2	2.6	4.6
Total Cover	63.8	30.0	38.0	62.8	20.8	39.8
Midland						
Naturalized Grass	10.4	5.0	17.6	18.8	6.4	11.8
Cool Season Grass	4.6	1.6	9.4	9.0	0.6	7.6
Warm Season Grass	37.2	20.4	7.0	14.8	8.0	9.2
Sedges	15.2	3.8	11.6	23.4	6.0	6.2
Total Cover	67.4	30.8	45.6	66.0	21.0	34.8
Lowland						
Naturalized Grass	1.8	5.4	4.6	0.0	0.4	0.0
Cool Season Grass	4.8	0.4	14.6	4.2	3.6	13.4
Warm Season Grass	5.2	3.0	0.2	0.0	0.6	1.6
Sedges	36.2	10.2	19.6	31.4	16.6	19.6
Total Cover	48.0	19.0	39.0	35.6	21.2	34.6

Bold values are greater on the seasonlong treatment than on the deferred treatment.

Table 5. Mean basal cover (%) for the upland, midland, and lowland rangeland sites managed by seasonlong and two times over grazing treatments.

Range Site Plants	Seasonlong			Two Times Over		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Upland						
Naturalized Grass	13.8	5.0	13.6	14.9	2.2	2.7
Cool Season Grass	4.8	2.0	1.8	5.2	2.8	3.0
Warm Season Grass	30.0	11.2	19.8	31.3	20.6	26.4
Upland Sedges	14.2	2.6	4.6	11.4	4.3	5.6
Total Cover	62.8	20.8	39.8	62.8	29.9	37.7
Midland						
Naturalized Grass	18.8	6.4	11.8	21.9	7.8	7.0
Cool Season Grass	9.0	0.6	7.6	3.2	3.3	2.4
Warm Season Grass	14.8	8.0	9.2	30.8	18.0	25.4
Sedges	23.4	6.0	6.2	9.7	6.0	3.3
Total Cover	66.0	21.0	34.8	65.6	35.1	38.1
Lowland						
Naturalized Grass	0.0	0.4	0.0	4.1	4.4	7.7
Cool Season Grass	4.2	3.6	13.4	2.1	3.8	6.6
Warm Season Grass	0.0	0.6	1.6	5.2	3.6	4.7
Sedges	31.4	16.6	19.6	33.4	13.2	14.8
Total Cover	35.6	21.2	34.6	44.8	25.0	33.8

Bold values are greater on the two times over treatment than on the seasonlong treatment.

Table 6. Mean basal cover (%) for the upland, midland, and lowland rangeland sites managed by deferred and two times over grazing treatments.

Range Site Plants	Deferred			Two Times Over		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Upland						
Naturalized Grass	12.8	0.0	6.8	14.9	2.2	2.7
Cool Season Grass	8.2	0.2	5.6	5.2	2.8	3.0
Warm Season Grass	27.4	26.0	21.8	31.3	20.6	26.4
Upland Sedges	15.4	3.8	3.8	11.4	4.3	5.6
Total Cover	63.8	30.0	38.0	62.8	29.9	37.7
Midland						
Naturalized Grass	10.4	5.0	17.6	21.9	7.8	7.0
Cool Season Grass	4.6	1.6	9.4	3.2	3.3	2.4
Warm Season Grass	37.2	20.4	7.0	30.8	18.0	25.4
Sedges	15.2	3.8	11.6	9.7	6.0	3.3
Total Cover	67.4	30.8	45.6	65.6	35.1	38.1
Lowland						
Naturalized Grass	1.8	5.4	4.6	4.1	4.4	7.7
Cool Season Grass	4.8	0.4	14.6	2.1	3.8	6.6
Warm Season Grass	5.2	3.0	0.2	5.2	3.6	4.7
Sedges	36.2	10.2	19.6	33.4	13.2	14.8
Total Cover	48.0	19.0	39.0	44.8	25.0	33.8

Bold values are greater on the two times over treatment than on the deferred treatment.

Table 7. Grazing treatment stocking rate, percent utilization, and percent of data periods with greater herbage biomass on grazed area than on the ungrazed area, mean of 3 years.

Grazing Treatment		Stocking Rate	Plant Communities		
			Upland	Midland	Lowland
1 Pasture		1.46 ac/AUM			
	Seasonlong				
1 X Over	% Utilization		-43	-36	-8
	% Greater Herbage on Grazed Area		0	13	27
2 Pasture		0.93 ac/AUM			
	Switchback				
3& 4 X Over	% Utilization		-33	-27	+11
	% Greater Herbage on Grazed Area		10	20	53
3 Pasture		0.87 ac/AUM			
	1p. Deferred				
2p. 2 X Over	% Utilization		-39	-24	-3
	% Greater Herbage on Grazed Area		0	20	40
3 Pasture		1.00 ac/AUM			
	3p. 2 X Over				
	% Utilization		-44	-22	-3
	% Greater Herbage on Grazed Area		7	25	31

Table 8. Visual obstruction measurements (VOM) for vegetation at 0% and 100% of the height-density pole and percent of 100% VOM readings below, at, and above 1.5 dm during spring and fall, mean of two years.

Grazing Treatment	Spring					Fall				
	0% VOM dm	100% VOM dm	Below 1.5 dm	At 1.5 dm	Above 1.5 dm	0% VOM dm	100% VOM dm	Below 1.5 dm	At 1.5 dm	Above 1.5 dm
1 Pasture	3.9	1.3	57	19	24	5.1	1.7	34	19	47
Seasonlong										
1 X Over						4.5 dm	1.5 dm			55%
2 Pasture	4.6	1.7	37	22	41	4.5	1.7	45	19	36
Switchback										
3& 4 X Over						4.6 dm	1.7 dm			59%
3 Pasture	4.9	1.6	38	21	41	5.3	1.8	31	20	49
1p. Deferred										
2p. 2 X Over						5.1 dm	1.7 dm			66%
3 Pasture	5.8	2.0	22	25	53	6.0	2.0	27	16	57
3p. 2 X Over						5.9 dm	2.0 dm			76%

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Sandhill Habitats

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1188

The Sandhills region in southeastern North Dakota is a large island of exceptional native plant communities surrounded by replacement communities of cropland and associated plants. This modern refugium requires comprehensive management practices that maintains the native vegetation and wildlife, the agricultural economic base, and the wholesome lifestyle of the human residents of the region.

The habitat types on the Sandhills region were described quantitatively by vegetation composition, topography, and soil characteristics. Similar habitat types were mapped into four distinct associations and the surface area determined.

The Sandhills region is located in Ransom and Richland counties in southeastern North Dakota between R52W-R54W and T133N-T136N comprised of 63,240 acres (25,593 ha) of private land and 67,320 acres (27,244 ha) of public land in the north unit of the Sheyenne National Grasslands administered by USDA Forest Service and managed in cooperation with the Sheyenne Valley Grazing Association. The public land is managed for grazing beef cattle, wildlife, and dispersed recreation. The private land is managed for grazing by beef cattle, hay production, and some areas are farmed for livestock feed and cash crops.

The regional geologic formation is the Glacial Sheyenne Delta formed during the latter portion of Wisconsin Glaciation. The glacial

Sheyenne River carrying a large load of clay, sand, and gravel emptied into Glacial Lake Agassiz. A layer of nearly impervious silts and clays formed in the lower portion of the delta which is responsible for the relatively high water table of the area. A thick layer of well sorted sands formed on the upper portion of the delta which is responsible for the sandhill appearance of the region.

The region has a continental climate with cold winters and hot summers. Data from the McLeod Weather Substation (US Dept. Com. 1973) show that the long term mean annual temperature is 41.9° F (5.5° C). January is the coldest month with a mean temperature of 7.7° F (-13.5° C). July and August are the warmest months with mean temperatures of 70.9° F (21.6° C) and 69.9° F (21.1° C), respectively. The long term mean annual precipitation is 19.6 inches (497.3 mm) with 84.8% (16.6 inches, 421.6 mm) occurring during the perennial plant growing season, April to October.

The vegetation consists of native forest, woodland, and grassland communities and non-native replacement communities (cropland) separated into eleven habitat types with distinctive topography and soil characteristics. Homogeneous physiographic sites with closely related distribution were grouped in four mappable complexes of habitat associations (figure 1, table 1).

FIGURE 1. HABITAT ASSOCIATIONS ON THE SHEYENNE NATIONAL GRASSLANDS

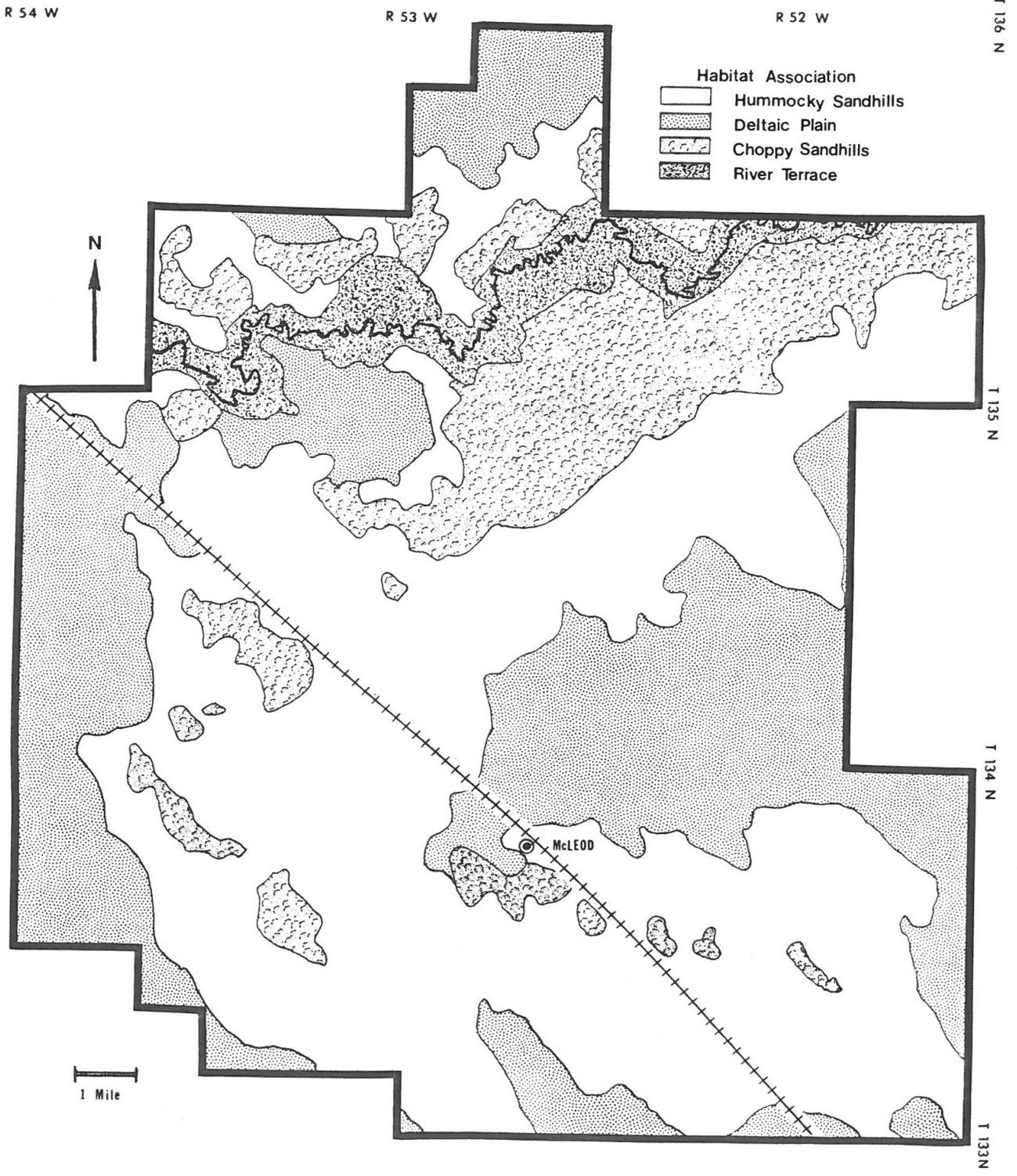


Table 1. Surface area of Habitat Types and Habitat Complexes.

Habitat Complex Habitat Type	Hectare	Acre	Percentage
Hummocky Sandhills	26,505.4	65,494	50.16
Upland Grassland	13,917.2	34,389	26.34
Midland Grassland	6,701.0	16,558	12.68
Lowland Grassland	5,154.7	12,737	9.76
Cropland	732.5	1,810	1.39
Deltaic Plain	15,686.6	38,761	29.69
Midland Grassland	5,858.4	14,476	11.09
Lowland Grassland	2,180.1	5,387	4.13
Cropland	7,648.0	18,898	14.47
Choppy Sandhills	7,758.1	19,170	14.68
Upland Woodland	4,967.3	12,269	9.40
Open Grassland	2,792.8	6,901	5.29
River Terrace	2,887.5	7,135	5.46
Riparian Forest	2,310.8	5,710	4.37
Cropland	576.7	1,425	1.09

Data from Manske 1980.

Hummocky Sandhills

The Hummocky Sandhills consists of 65,494 acres (26,505 ha), 50.16% of the total area (table 1). The topography is gently rolling and undulating hummocks (small conical hills) with relief of 5 to 10 feet (1.5-3 m) and slope of 5 to 10%. The soils are primarily loamy fine sand with low available soil water. The native vegetation is divided into three grassland communities expressed in distinct belts on each hummock, upland (mixed grass prairie), midland (tall grass prairie), and lowlands (sedge meadow). A few swales are deeper than average and support wet land vegetation of sedges, cattails, and willows. There are a few scattered areas of native quaking aspen and cottonwood trees and a few small areas of planted shelter belts and tree claims remaining on old homestead sites; along with a few plants of asparagus, rhubarb, and lilac.

Upland Grassland

The Upland Grassland Habitat exists on the summit and shoulder slopes of each hummock; the combined sites consist of 34,389 acres (13,917 ha), 26.34% of the total area (table 1). The Serden and Maddock soils are loamy fine sand that are low in organic matter, low in available soil water, rapid in permeability, and pH between 6.6 and 7.3 (table 2). The vegetation is mixed grass prairie with major species of blue grama, needle and thread, and upland sedge with a total percent basal cover of 34.12%. Forb total density is 127.44 plants per m² and shrub total density is 5.38 plants per m² (table 3).

Midland Grassland

The Midland Grassland Habitat exists on the back slope and extends into the foot slope of each hummock; the combined sites consist of 16,558 acres (6,701 ha), 12.68% of the total area (table 1). The Hecla and Hamar soils are loamy fine sand that are high in organic matter, low to moderate in available soil water, and rapid in permeability, and Hecla has a pH between 6.6 and 7.3, and Hamar has a pH between 7.4 and 7.8 (table 2). The vegetation is tall grass prairie with major species of big bluestem, little bluestem, and switchgrass with a total percent basal cover of 45.32%. Forb total density is 87.89 plants per m² and shrub total density is 6.18 plants per m² (table 4).

Lowland Grassland

The Lowland Grassland Habitat exists on the foot and toe slopes of each hummock; the combined sites consist of 12,737 acres (5,154 ha), 9.76% of the total area (table 1). The Arveson-Fossum and Venlo soils are fine sandy loam that are high in organic matter, moderate and low in available soil water, respectively, and rapid in permeability, and Arveson-Fossum has a pH between 7.4 and 8.4, and Venlo has a pH between 6.6 and 7.3 (table 2). The vegetation is sedge meadow with major species of woolly sedge, northern reedgrass, and baltic rush with a total percent basal cover of 34.04%. Forb total density is 71.72 plants per m² and shrub total density is 1.76 plants per m² (table 5).

Cropland

The Cropland Habitat exists on low relief slopes; the combined sites consist of 1,810 acres (732 ha), 1.39% of the total area (table 1). The large flat areas of Hecla and Hamar soils that are loamy fine sand, high in organic matter, low to moderate in available soil water, and rapid in permeability, and pH between 6.6 and 7.3 and between 7.4 and 7.8, respectively (table 2). The vegetation is non-native (cropland) replacement communities with associated cultivated and introduced plant species. The major crops are corn for silage and some for grain, sunflowers, and alfalfa for hay. There are 37 acres (15 ha) of planted tree shelterbelts associated with the cropland.

Table 2. Soil characteristics for habitat types of the Hummocky Sandhills Habitat Complex.

Habitat Type	Soil Series	Texture	Organic Matter	Available Water	Permeability	pH
Upland Grassland	Serden	loamy fine sand	low	low	rapid	6.6-7.3
	Maddock	loamy fine sand	low	low	rapid	6.6-7.3
Midland Grassland	Hecla	loamy fine sand	high	low to moderate	rapid	6.6-7.3
	Hamar	loamy fine sand	high	low to moderate	rapid	7.4-7.8
Lowland Grassland	Arveson-Fossum	fine sandy loam	high	moderate	rapid	7.4-8.4
	Venlo	fine sandy loam	high	low	rapid	6.6-7.3

Data from Thompson and Joos 1975.

Table 3. Plant species composition of the Upland Grassland Habitat Type of the Hummocky Sandhills Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Blue grama	11.05	Late Succession	49.30
Prairie sandreed	2.28	Mid Succession	17.52
Little bluestem	0.89	Early Succession	0.22
Sand dropseed	0.51	Biennial	
Other n=12	1.59	Late Succession	2.00
Cool season		Annual	
Needle and thread	2.57	Mid Succession	23.66
Porcupine grass	1.00	Early Succession	33.68
Prairie junegrass	0.58	Lycopods	
Other n=3	0.55	Horsetail	0.98
Naturalized grass		Shrubs	#/m ²
Kentucky bluegrass	7.56	Lead plant	2.57
Sedge		Prairie wild rose	1.91
Upland sedge	5.54	Wild spiraea	0.68
		Other n=6	0.22

Data from Manske 1980.

Table 4. Plant species composition of the Midland Grassland Habitat Type of the Hummocky Sandhills Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Little bluestem	6.76	Late Succession	39.83
Big bluestem	6.75	Mid Succession	17.88
Blue grama	2.81	Early Succession	0.70
Switchgrass	2.04	Biennial	
Prairie sandreed	0.72	Late Succession	0.85
Prairie dropseed	0.66	Mid Succession	0.48
Other n=13	1.70	Early Succession	0.22
Cool season		Annual	
Northern reedgrass	1.33	Mid Succession	12.70
Porcupine grass	0.75	Early Succession	13.47
Needle and Thread	0.43	Lycopods	
Other n=4	0.61	Horsetail	1.76
Naturalized grass		Shrubs	#/m ²
Kentucky bluegrass	11.58	Lead plant	2.24
Sedge		Wild spiraea	2.06
Upland sedge	2.58	Prairie wild rose	0.69
Lowland sedge	2.12	Other n=8	1.19
Spikerush	3.37		
Rush	1.11		

Data from Manske 1980.

Table 5. Plant species composition of the Lowland Grassland Habitat Type of the Hummocky Sandhills Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Switchgrass	2.24	Late Succession	56.84
Big bluestem	0.46	Mid Succession	3.03
Prairie cordgrass	0.35	Early Succession	7.66
Other n=11	1.03	Biennial	
Cool season		Mid Succession	0.52
Northern reedgrass	3.81	Annual	
Other n=3	0.18	Mid Succession	1.73
Naturalized grass		Early Succession	1.10
Kentucky bluegrass	5.31	Lycopods	
Sedge		Horsetail	0.84
Lowland sedge	8.75	Shrubs	
Spikerush	6.79	Wild licorice	0.56
Bulrush	1.55	Slender willow	0.46
Rush	3.57	Wild spirarea	0.32
		Other n=7	0.42

Data from Manske 1980.

Deltaic Plain

The Deltaic Plain consists of 38,761 acres (15,686 ha), 29.69% of the total area (table 1). The topography is nearly level with relief of 1 to 5 feet (0.3-1.5 m) but mostly 1 to 2 feet (0.3-0.6 m) and slope less than 2%. The soils are primarily loam that are high in organic matter, high to moderate in available soil water, and rapid to moderate in permeability. The entire complex has a high water table. The native vegetation is divided into two grassland communities related to depth to water table, midland (tall grass prairie) with slightly deeper depth to water table, and lowland (sedge meadow) with lower depth to water table. A few swales are deeper than average and support wetland vegetation of sedges, cattails, and willows. A very small area of less than 15 acres (6.1 ha), 0.01% of the total area has higher relief and supports mixed grass prairie vegetation.

Midland Grassland

The Midland Grassland Habitat exists in the landscape on areas of slight rises in topography; the combined sites consist of 14,476 acres (5,858 ha), 11.09% of the total area (table 1). The six major soil series are Borup, Embden, Gardena, Glyndon, Hecla, and Tiffany that are loam to fine sandy loam, high in organic matter, high to moderate in available soil water, rapid to moderate in permeability, and pH between 6.6 and 8.4 (table 6). The vegetation is tall grass prairie with major species of big bluestem, little bluestem, and Indiangrass with a total percent basal cover of 47.71%. Forb total density is 102.70 plants per m² and shrub total density is 3.69 plants per m² (table 7).

Lowland Grassland

The Lowland Grassland Habitat exists in the landscape on areas of slight depressions in topography; the combined sites consist of 5,387 acres (2,180 ha), 4.13% of the total area (table 1). The Arveson-Fossum and Venlo soils are loam and fine sandy loam that are high in organic matter, moderate to low in available soil water, rapid in permeability, and has pH between 6.6 and 8.4 (table 6). The vegetation is sedge meadow with major species of woolly sedge, northern reedgrass, and lowland sedge with a total percent basal cover is 41.78%. Forb total density is 70.80 plants per m² and shrub total density is 0.0 plants per m² (table 8).

Cropland

The Cropland Habitat exists on a large portion of the landscape with nearly level topography; the combined sites consist of 18,898 acres (7,648 ha), 14.47% of the total area (table 1). The soils are loam and fine sandy loam that are high in organic matter, high to moderate in available soil water, rapid to moderate in permeability, and pH between 6.6 and 8.4 (table 6). The vegetation is non-native (cropland) replacement communities with associated cultivated and introduced plant species. The major crops are corn for grain and some for silage, alfalfa, sunflowers, and a very small amount of millet and oats. There are 402 acres (162 ha) of planted tree shelterbelts associated with the cropland.

Table 6. Soil characteristics for habitat types of the Deltaic Plain Habitat Complex.

Habitat Type	Soil Series	Texture	Organic Matter	Available Water	Permeability	pH
Midland Grassland	Borup	loam	high	high	moderate	7.4-7.8
	Embden	fine sandy loam	high	moderate	rapid	6.6-7.3
	Gardena	loam	high	high	moderate	6.6-7.8
	Glyndon	silt loam	high	high	rapid	6.6-8.4
	Hecla	fine sandy loam	high	moderate	rapid	6.6-7.3
	Tiffany	loam	high	moderate	rapid	6.6-7.3
Lowland Grassland	Arveson-Fossum	loam	high	moderate	rapid	7.4-8.4
	Venlo	fine sandy loam	high	low	rapid	6.6-7.3

Data from Thompson and Joos 1975.

Table 7. Plant species composition of the Midland Grassland Habitat Type of the Deltaic Plain Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Little bluestem	8.49	Late Succession	18.32
Big bluestem	6.33	Mid Succession	1.74
Indian grass	3.93	Early Succession	37.03
Switchgrass	2.51	Biennial	
Side oat grama	1.58	Early Succession	26.52
Other n=10	4.53	Annual	
Cool season		Late Succession	2.78
Northern reedgrass	0.29	Mid Succession	2.78
Other n=2	0.06	Early Succession	3.16
Naturalized grass		Lycopods	
Kentucky bluegrass	10.78	Horsetail	10.28
Sedge		Shrubs	
Upland sedge	0.80	Western snowberry	3.32
Lowland sedge	1.84	Wild spiraea	0.37
Spikerush	3.64		
Rush	0.63		

Data from Manske 1980.

Table 8. Plant species composition of the Lowland Grassland Habitat Type of the Deltaic Plain Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Switchgrass	2.56	Late Succession	35.90
Big bluestem	1.11	Early Succession	26.47
Indian grass	1.00	Biennial	
Slender wheatgrass	0.93	Early Succession	1.48
Other n=11	5.86	Annual	
Cool season		Late Succession	0.74
Northern reedgrass	3.89	Mid Succession	0.19
Other n=2	0.24	Early Succession	0.19
Naturalized grass		Lycopods	
Kentucky bluegrass	6.40	Horsetail	5.18
Sedge		Shrubs	#/m ²
Lowland sedge	8.75	No shrubs	
Spikerush	8.82		
Rush	2.22		

Data from Manske 1980.

Choppy Sandhills

The Choppy Sandhills consists of 19,170 acres (7,758 ha), 14.68% of the total area (table 1). The topography of these large sandhills is very rough and choppy with relief of 5 to 50 feet (1.5-15.3 m) but usually 10 to 20 feet (3-6.1 m) and slope of 10 to 20%. The soil is fine sand that is low, moderate, or high in organic matter, low to moderate in available soil water, rapid in permeability, and pH between 6.6 and 7.8. The vegetation is divided into native woodland and grassland.

Upland Woodland

The Upland Woodland Habitat exists on various slopes and depressions of the choppy topography; the combined sites consist of 12,269 acres (4,967 ha), 9.40% of the total area (table 1). The Serden soil makes up over 90% of this habitat and is fine sand that is low in organic matter, low in available soil water, rapid in permeability, and pH between 6.6 and 7.3 (table 9). The vegetation grades into two plant communities, the bur oak woodland and the bur oak savanna. The bur oak woodland occurs as groves with the denser portions on the lower slopes and in the depressions between slopes. The bur oak savanna exists on the edges of the groves, on portions of the higher slopes, and on areas between the groves. Curtis (1959) defines a savanna as an area with 1 tree per acre (0.4/ha) that has 50% canopy cover or less. The combined area of

woodland and savanna has 64% canopy cover and a mean tree density of 62 per acre with a range from 12.2 to 117.4 trees per acre (table 10). The mean basal area (DBH) is 39 ft²/acre, or 0.09% of the total land area covered by tree trunk. The understory of the bur oak groves is mostly shrubs and forbs with little grass. Forb total density is 17.23 plants per m², shrub total density is 7.42 plants per m², and sapling total density is 0.52 plants per m². Grass total percent basal cover was only 2.74% (table 11).

Open Grassland

The Open Grassland Habitat exists on the choppy sandhills topography between the areas of bur oak woodlands and bur oak savannas; the combined sites consist of 6,901 acres (2,792 ha), 5.29% of the total area (table 1). The Serden and Maddock soils exist on the upper slopes and are fine sand and loamy fine sand that are low to moderate in organic matter, low in available soil water, rapid in permeability, and pH between 6.6 and 7.3. The Hamar and Venlo soils exist on the lower slopes and are loamy fine sand and fine sandy loam that are high in organic matter, low to moderate in available soil water, rapid in permeability, and pH between 6.6 and 7.8 (table 9). The vegetation is thin mixed grass prairie with major species of blue grama, upland sedge, and sand dropseed with a total percent basal cover of only 8.9%. Forb total density is 55.31 plants per m² and shrub total density is 3.31 plants per m² (table 12).

Table 9. Soil characteristics for habitat types of the Choppy Sandhills Habitat Complex.

Habitat Type	Soil Series	Texture	Organic Matter	Available Water	Permeability	pH
Upland Woodland	Serden	fine sand	low	low	rapid	6.6-7.3
	Maddock	loamy fine sand	moderate	low	rapid	6.6-7.3
Open Grassland	Hamar	loamy fine sand	high	low to moderate	rapid	7.4-7.8
	Venlo	fine sandy loam	high	low	rapid	6.6-7.3

Data from Thompson and Joos 1975.

Table 10. Tree species composition of the Upland Woodland Habitat Type of the Choppy Sandhills Habitat Complex.

Tree Species	Tree Density		DBH Basal Area		
	DBH>3 in	#/ha	#/acre	m ² /ha	ft ² /acre
Bur oak		81.79	33.10	3.90	17.00
Quaking aspen		26.44	10.70	0.55	2.30
Green ash		15.07	6.10	0.53	2.30
Cottonwood		13.34	5.40	2.41	10.50
Basswood		5.19	2.10	0.30	1.30
Hackberry		3.21	1.30	0.39	1.70
American elm		1.98	0.80	0.48	2.10
Box elder		1.98	0.80	0.16	0.70
Prairie willow		1.24	0.50	0.10	0.40
Choke cherry		1.24	0.50	0.01	0.04
White willow		0.99	0.40	0.12	0.50
Ironwood		0.25	0.10	0.01	0.02
Russian olive		0.25	0.10	0.001	0.003
Total		153.20	62.00		

Data from Manske 1980.

Table 11. Plant species composition of the Upland Woodland Habitat Type of the Choppy Sandhills Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Little bluestem	0.07	Late Succession	8.51
Cool season		Mid Succession	0.38
Porcupine grass	0.03	Early Succession	3.40
Naturalized grass		Biennial	
Kentucky bluegrass	1.70	Late Succession	0.19
Sedge		Early Succession	2.28
Upland sedge	0.05	Annual	
Woodland sedge	0.89	Mid Succession	2.00
		Early Succession	0.47
		Shrubs	
		Poison ivy	2.56
		Western snowberry	1.36
		Choke cherry	0.91
		Juneberry	0.58
		Other n=16	2.01
		Tree saplings	
		Other n=5	0.52

Data from Hanson 1976.

Table 12. Plant species composition of the Open Grassland Habitat Type of the Choppy Sandhills Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Blue grama	1.42	Late Succession	18.10
Sand dropseed	1.02	Biennial	
Prairie sandreed	0.29	Mid Succession	0.08
Other n=7	0.45	Annual	
Cool season		Late Succession	0.79
Needle and thread	0.68	Mid Succession	30.00
Prairie junegrass	0.35	Early Succession	5.94
Other n=1	0.09	Lycopods	
Naturalized grass		Horsetail	0.40
Kentucky bluegrass	2.97	Shrubs	#/m ²
Sedge		Prairie wild rose	1.99
Upland sedge	1.46	Lead plant	0.57
Sand sedge	0.21	Wild spiraea	0.22
		Western snowberry	0.22
		Other n=4	0.31

Data from Hanson 1976.

River Terrace

The River Terrace exists along the Sheyenne River and its spring fed tributaries and consists of 7,135 acres (2,887 ha), 5.46% of the total area (table 1). The topography is nearly level with very little or no relief that has a gradual slope of 0.3% away from the present river channel which has steep banks. The alluvial terrace extends from the river channel outward to the edge of the river valley which has a very steep escarpment with 25 to 30 feet (7.6-15.3 m) relief and a slope of greater than 20%. The soils are silt loam that is moderate to high in organic matter, high in available soil water, slow to moderate in permeability, and pH between 6.6 and 7.8. The vegetation is 80% native forest and 20% cleared and developed cropland. The native forest is divided into two plant communities of elm-basswood and green ash-boxelder communities. A few oxbows form wetlands with sedges, cattails, and willows.

Riparian Forest

The Riparian Forest Habitat exists on the alluvial terrace and consists of 5,710 acres (2,310 ha), 4.37% of the total area (table 1). The Fairdale, LaDelle, and Wahpeton soils are silt loam and silt clay loam that are high to moderate in organic matter, high in available soil water, moderate to slow in permeability, and pH between 6.6 and 7.8 (table 13). The forest vegetation is elm-basswood and green ash-

boxelder communities that are intermixed and integrate on a continuum basis. The combined forest has nearly 100% canopy cover and a mean tree density of 163 per acre (403 trees per ha). The mean basal area (DBH) is 217.1 ft² per acre (50 m² per ha) or 0.5% of the total land area covered by tree trunk (table 14). The understory is quite sparse. The graminoid total percent basal cover is 16.8%. Forb total density is 62.3 plants per m², shrub total density is 0.75 plants per m², and sapling density is 0.18 plants per m² (table 15).

Cropland

The Cropland Habitat exists in areas cleared of forest vegetation; the combined sites consist of 1,425 acres (577 ha), 1.1% of the total area (table 1). The soils are silt loam and silt clay loam that are high to moderate in organic matter, high in available soil water, moderate to slow in permeability, and pH between 6.6 and 7.8 (table 13). The vegetation is non-native (cropland) replacement communities with associated cultivated and introduced plant species. The major crops are corn for grain, sunflowers, alfalfa, and some soybeans.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.

Table 13. Soil characteristics for habitat types of the River Terrace Habitat Complex.

Habitat Type	Soil Series	Texture	Organic Matter	Available Water	Permeability	pH
Riparian Forest	Fairdale	silt loam	moderate	high	moderate	7.4-7.8
	LaDelle	silt clay loam	high	high	moderate	6.6-7.8
	Wahpeton	silty clay	high	high	slow	6.6-7.3

Data from Thompson and Joos 1975.

Table 14. Tree species composition of the Riparian Forest Habitat Type of the River Terrace Habitat Complex.

Tree Species	Tree Density		DBH Basal Area		
	DBH>3 in	#/ha	#/acre	m ² /ha	ft ² /acre
Basswood		158.81	64.27	20.27	88.31
American elm		103.36	41.83	18.19	79.26
Green ash		63.03	25.51	4.69	20.42
Box elder		32.79	13.27	3.87	16.87
Hackberry		20.16	8.16	0.96	4.20
Bur oak		15.12	6.12	1.64	7.13
Ironwood		10.08	4.08	0.20	0.88
Total		403.36	163.24		

Data from Manske 1980.

Table 15. Plant species composition of the Riparian Forest Habitat Type of the River Terrace Habitat Complex.

Graminoids	Percent basal cover	Forbs	#/m ²
Warm season		Perennial	
Bottlebrush	1.65	Late Succession	25.78
Virginia wildrye	0.40	Mid Succession	2.40
Cool season		Annual	
Blackseed ricegrass	0.30	Late Succession	0.05
Naturalized grass		Mid Succession	34.10
Kentucky bluegrass	0.05	Shrubs	#/m ²
Sedge		Western snowberry	0.43
Woodland sedge	14.40	Missouri gooseberry	0.23
		Other n=4	0.09
		Tree Sapling	
		Other n=5	0.18

Data from Nelson 1964.

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Activity and Habitat Use by Prairie Chicken of the Sandhills Region

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1191

Greater Prairie Chicken, *Tympanuchus cupido pinnatus*, require various types of habitats to perform their annual seasonal activities. A six year study was conducted to determine the relationships among the major activities of courtship, nesting, brood rearing, roosting, and winter survival performed during seasonal periods and the habitats selected for use from the available habitat types on the Sandhills region.

Procedure for Courtship Activity

Methods used for the spring census of prairie chicken followed the standard procedures described by Grange (1948) and Kirsch (1956). Listening routes were traversed during ½ hour before to 1 hour after sunrise to locate new display grounds. Stops were made at ¼, ½, to 1 mile intervals, motor was shut off, and observer moved away from vehicle to listen for prairie grouse display sounds for at least 2 or 3 minutes. Stops were plotted on a map with arrows drawn to show direction and estimated distance to grounds heard.

Each known display ground was visited 3 to 12 times per census period to count active male birds. The presence of all female birds observed was also recorded. Special precautions were made not to disturb the grounds by flushing the birds so other grounds in the vicinity could be censused without recounting any birds. A 7 power binoculars and a 25 power spotting scope were invaluable in census surveillance to record all active birds, and separation of male and female, and prairie chicken, sharptailed grouse, and hybrid.

Levels of male and female bird's activity on display grounds was evaluated. The relationship of daily and weekly display ground activity by male and female birds was determined as a percentage of the maximum daily and weekly male activity on the same grounds.

Prairie grouse spring courtship display grounds are anchored on the upland mixed grass prairie community with vegetation generally with short stature. It is not known if the Upland mixed

grass prairie vegetation is acceptable as sites for display grounds without grazing management and not known if the Midland tall grass prairie community is acceptable as suitable sites for display ground habitat without grazing and mowing management. To assess this unknown, the distance from the center of all booming grounds and mixed display grounds with male prairie chicken was measured to the nearest livestock watering facility because the vegetation near livestock water facilities tend to be grazed a little shorter than the typical level of vegetation on similar communities away from livestock watering facilities.

The location of prairie grouse display grounds appear to be associated with concealment cover adjacent or very near. The visual obstruction quality of display ground concealment cover was measured with the height-density pole method developed by Robel et al. (1970a) and modified by Kirsch (1974). Twenty five pole sets with an interval of 12 paces were made in homogeneous vegetation along transects of 275 meters (900 ft) long. Four readings at a height of 1.0 meter and a distance of 4.0 meters (13 ft) were made at each pole set for the 0% and 100% visual obstruction measurements (VOM) to the nearest 0.5 decimeter (2 inches) at the four major compass directions. A mean 100% VOM at 1.5 dm (5.9 in) was considered to be good concealment cover (Manske 1981, Higgins and Barker 1982).

The annual cadastral description of the location of all active display grounds to the quarter, quarter, quarter section (ten acres) was recorded. Evaluation of the annual locations would indicate stability or movement of display grounds. The display ground locations cluster into three population districts. The addition of new display grounds would indicate occupied habitat expansion.

Procedure for Nesting Activity

Determination of successful nest site habitat required to know the location of representative nests. Two methods were used to locate nest sites. The cable-chain drag as described by Higgins, Kirsch, and Ball (1969) and Higgins et al. (1977) consisted of a 174 ft (53 m) length of 5/8 in (1.6 cm) steel cable

with three loops of ¼ in (0.6 cm) steel chain attached to cable with swivels. The cable-chain drag was pulled between two vehicles to survey suitable nest habitat. Nests were located by the sites of flushed hens and marked with a flag placed fifteen paces to the north. The cable-chain drag was used to survey 2,640 acres (1068 ha). Trained bird dogs were also used to locate prairie grouse nest sites with the observer on foot. The dogs were used to survey 2,903 acres (1175 ha).

Data collected at each nest site located was the number of eggs, major plant species, dimensions of the nest site, distance from the nest site to short (< 1 dm) vegetation, topographic relief, percent slope, and aspect. Nest location was marked on a map and the distance to the nearest display ground was measured. When nest was no longer used, the nest cover was evaluated by the height-density pole, with one set in center of nest, four sets two meters out, and four sets four meters out with a total of 36 readings.

Procedure for Brooding Activity

Determination of successful brooding habitat required to know the location of representative brood sites. Two methods were used to locate brood rearing sites. Trained bird dogs were used to locate prairie grouse broods with two observers on horse back. The dogs were used to survey 41,633 acres (16,849 ha). Vehicle transects with a total of 50 miles (80.5 km) long that dissected all habitat types of the Hummocky Sandhills and Deltaic Plain Habitat Associations were traversed 3 times every two weeks during the growing season. Data collected at each site that broods were located was the number of chicks, estimated age, habitat type, dominant plants, the cadastral description, and allotment and pasture. Representative brood habitat quality was measured by the height-density pole.

Procedure for Roosting Activity

Prairie grouse spend the night period from just after sundown to just before sunrise on a ground roost and much of the mid day period between morning and evening feeding periods is spent on day roosts and doing other loafing activities. Prairie grouse roosts were located during all seasonal periods with the aid of trained dogs. During night searches, the dogs were equipped with a bell. Several night roosts without birds were located during the day. All of the day roosts were occupied by a bird.

Procedure for Winter Activity

The northern winters on the Sandhills region of southeastern North Dakota can be severe and are undoubtedly stressful for prairie grouse. Survival during the winter period is critical for the prairie grouse.

A seven winter study to locate prairie grouse and observe their activity during the winter months, 16 November to 31 March, was conducted. Two methods were used to locate prairie grouse. Road transects were traversed by driving a vehicle on all passable roads and trails, stopping at ¼ or ½ mile intervals and scanning the surrounding area for prairie grouse with binoculars and observing their activity with a spotting scope. The areas that could not be reached by vehicle were covered by foot transects accompanied by trained bird dogs. Snowshoes were required most of the time. The data collected at each prairie grouse observations was cadastral location, time, general weather conditions, land use, habitat type, dominant plant species, activity and behavior of the birds. Also daily mileage of road transects, distance walked, and acreage covered by the dogs for foot transects were recorded.

Procedure for Prairie Chicken Habitat Usage

This habitat usage study was conducted to determine which habitats were being used by prairie chicken during their annual seasonal activities. The four seasonal periods were: Spring 1 April to 15 June, Summer 16 June to 31 August, Fall 1 September to 15 November, and Winter 16 November to 31 March.

The landscape of the Sandhills region was separated into eleven habitat types based on vegetation composition, topography, and soil characteristics. The vegetation map was a composite developed from homogeneous reflectance of two sets of Landsat-2 images from May and August and one set of Skylab photographs, from June. The soil map was developed from homogeneous regions of similar soil texture in General Soils Maps of Ransom and Richland Counties. The topographic map was developed from homogeneous physiographic regions of nine US Geological Survey Topographic Quadrangle Maps. These three developed maps were field checked and then the homogeneous physiographic sites with closely related distribution were grouped into four mappable complexes of habitat associations. Acreages of each habitat type and habitat association were determined by 3 replications of electronic planimeter and dot grid

techniques. The resulting information was reported by Manske (2020) in Sandhill Habitats (figure 2 and table 22).

Observations of prairie chicken performing annual seasonal activities were made during foot transects with bird dogs and during vehicle transects. The data collected at each prairie chicken observation was: cadastral description, allotment and pasture location, land use, habitat type, dominant plant species, date, time of day, general weather conditions, the species and sex of each prairie grouse if it could be determined, and behavioral activity of the bird.

The prairie chicken habitat use index developed by Robel et al. (1970b) (% of bird locations/% of study area) was used to indicate relative habitat usage by prairie chicken during four seasonal periods. A habitat use index greater than 1.0 indicates selection of that habitat was greater than expected by chance use. Index values less than 1.0 indicates selection at less than the availability of that habitat. An index value of zero indicates avoidance of that habitat type.

Results for Courtship Activity

Prairie chicken gather every spring on communal display booming grounds for the purpose of courtship and mating. A few older male prairie chicken form on the booming grounds around 15 to 20 March followed soon afterward by the younger males.

During the early period, the males determine the pecking order and the boundaries of their display territories by intense skirmishes. The mechanism that triggers this ritualistic activity is a change in the balance of two hormones in the pituitary gland that is activated by the increase of day length in early spring. The change of hormones in the pituitary gland causes the male testes and female ovaries to enlarge and produce complimentary hormones that strongly influence the behavior of the birds. The auditory and visual signals of male prairie chicken in full courtship display further stimulates breeding behavior.

The male prairie chicken census indicates a low population during 1961 to 1970 with no more than 9 males counted in a year, but not all of the known grounds were visited until 1972.

During 1961 to 1967, all 56 allotments were grazed 6 months seasonlong from mid May to mid November, providing little adequate concealment habitat for the prairie chicken. During 1968 to 1970,

a few allotments were cross fenced and some multiple pastures were grazed one time per year with one of the pastures deferred until late season. In 1971, 18 pastures from 15 allotments, about 10% of the land, were grazed two times per year.

The spring prairie grouse census reflects the grazing management practice of the previous season or two. The spring census of 1971 found four booming grounds with 19 male prairie chickens. The spring census of 1972 found that 9 booming grounds had 55 males, 2 mixed grounds had 9 males, and 1 dancing ground had 4 males; these 12 display grounds had a huge increase of 68 male prairie chicken. Continuance of this increase, the spring census of 1973 found that 10 booming grounds had 71 males, 2 mixed grounds had 8 males, and 2 dancing grounds had 10 males; these 14 display grounds had an increase with 89 male prairie chicken (tables 1, 2, 3, and 4).

In 1974, 14 allotments, 26% of the land, had all pastures grazed 2 times per year. The number of pastures with two grazing periods per year increased each grazing season until the peak in 1978 when 54% of the land was managed with two grazing periods per year.

The spring census of 1975, found that 19 booming grounds had 116 males, 5 mixed grounds had 23 males, and 3 dancing grounds had 4 males; these 27 display grounds had an increase to 143 male prairie chicken. The spring census of 1977, found that 21 booming grounds had 160 males, and 5 mixed grounds had 29 males; these 26 display grounds had 189 male prairie chicken. The spring census of 1979, found that 29 booming grounds had 280 males, 9 mixed grounds had 57 males, and 1 dancing ground had 1 male; these 39 display grounds had a huge increase to 338 prairie chicken. The spring census of 1980, found 31 booming grounds had 352 males, 10 mixed grounds had 50 males, and 2 dancing grounds had 9 males; these 43 display grounds had an increase to 411 male prairie chicken (tables 1, 2, 3, and 4).

The display ground activity levels are assumed to be similar in male and female prairie chicken. The male birds start courtship activity on booming grounds around 15 to 20 March. The female birds are visible on booming grounds about a week later. Male birds arrive 1 hour to ½ hour before sunrise and most vocal activity occurs from dawn until ½ hour to 1 hour after sunrise, display activity slows down but continues until 8 or 9 o'clock depending on weather conditions or presence of female birds. Intense levels of courtship display

occurs from 7 to 28 April with peak activity from 14 to 20 April. Activity continues after 28 April at low intensity but has renewed activity during late May to mid June when renesting females return to the booming grounds (figure 1).

Male hybrid activity on display grounds was extremely erratic, they come and go, even during peak display periods (table 5). Very few female hybrids were identified showing interest on display grounds and only during peak display periods.

The male prairie chicken breakup into small groups after mid June but remain in the vicinity of the display ground all summer.

The distance from the center of the display ground to the nearest livestock watering facility was measured for 176 booming and mixed ground with active male prairie chicken. Most, 118 grounds (67%), were located near a livestock water facility with vegetation grazed shorter than the typical level and had a mean distance of 601 ft (183 m). The other display grounds, 58 grounds (33%), were greater than 1500 ft (457 m) from a livestock watering facility. 31 grounds (17.6%) were restricted to the upland mixed grass prairie community with short stature vegetation. 22 grounds (12.5%) had been mowed during the previous year. Only 5 grounds (2.8%) had male prairie chicken displaying on the midland tall grass prairie community that had not been mowed the previous year and was greater than 1500 ft (457 m) from livestock water. No prairie chicken males displayed on unmowed lowland sedge meadow community. The vegetation height stature had been reduced by grazing or mowing management on the sites of 140 grounds (79.5%) selected by male prairie chicken and the sites selected for only 36 grounds (20.5%) had vegetation at typical level.

The quality of concealment cover adjacent or very near spring display grounds was determined for 181 booming grounds by the height-density pole method. The concealment cover was very good with mean 100% VOM at greater than 1.5 dm (5.9 in) on 132 grounds (73%). The concealment cover was good with mean 100% VOM near 1.5 dm (5.9 in) on 27 grounds (15%). The concealment cover was poor with mean 100% VOM at less than 1.5 dm (5.9 in) on 22 grounds (12%). Most booming grounds, 159 grounds (88%), had good or very good concealment cover adjacent or very near with mean 100% VOM at or greater than 1.5 dm (5.9 in).

Prairie grouse census started in 1961 that located 6 display grounds. Two grounds were

counted with 5 male prairie chicken and 1 hybrid. By 1970 (year 10), the location of 10 display grounds was known, 8 had prairie chicken and 2 had sharptailed grouse. Only 3 grounds had been visited more than one time in 10 years and all 3 of these had moved 3 times. Young display grounds are not tied to a single location.

By 1980 (year 20), the location of 32 booming grounds was known (table 6). Only one booming ground had used the same location for 10 years. Five booming grounds had been known for only one or two years and had not yet moved. Twenty six (81%) of the booming grounds had changed locations. These booming grounds had been active for an average of 6.0 years, moved an average of 4.4 times, at a rate of movement during 74.0% of their active years. The mean distance moved was 0.69 miles (1.1 km). The mobility of each display ground was limited to a territory or movement zone of varying size with a mean of 0.67 X 0.40 miles (1.1 X 0.64 km) with 199 acres (80.5 ha) (table 6).

Also by year 20, the location of 11 mixed display grounds was known (table 7). Only one mixed ground had used the same location for 4 years. Ten (91%) of the mixed grounds had changed locations. These mixed grounds had been active for an average of 5.0 years, moved an average of 2.9 times, at a rate of movement during 69.0% of their active years. The mean distance moved was 0.35 miles (0.56 km). The mobility of each mixed ground was limited to a territory or movement zone of varying size with a mean of 0.34 X 0.20 miles (0.55 X 0.32 km) with 53 acres (21.5 ha) (table 7).

The prairie chicken population congregate into three major districts (figure 2). During the period of 1971 to 1980, the number of male prairie chicken, the number of booming grounds and mixed display grounds, and the quantity of occupied habitat greatly increased on each of the population districts.

The West Central District was located west of McLeod (tables 8 and 11). In 1975, it had 13 booming grounds with 66 male prairie chicken and 4 hybrids. During the consecutive five years, 9 booming grounds remained active, 2 booming grounds changed to mixed grounds, 1 booming ground was abandoned, 1 booming ground changed to a dancing ground, 5 new booming grounds were added, 3 new mixed grounds were added, and one dancing ground changed to a mixed ground and was added (table 11). During 1980, there were 15 booming grounds and 6 mixed grounds with 180 male prairie chicken and 5 hybrids (table 8 and figure 2).

The South East District was located south and east of McLeod (tables 9 and 11). In 1975, it had 8 booming grounds with 48 male prairie chicken and 1 hybrid. During the consecutive five years, 6 booming grounds remained active, 2 booming grounds changed to mixed grounds, 2 new booming grounds were added, and 2 new mixed grounds were added (table 11). During 1980, there were 8 booming grounds and 4 mixed grounds with 134 male prairie chicken and 1 hybrid (table 9 and figure 2).

The North East District was located north and east of McLeod (tables 10 and 11). In 1975, it had 2 booming grounds and 1 mixed ground with 25 male prairie chicken and 11 hybrid. During the consecutive five years, 2 booming grounds remained active, 1 mixed ground changed to a booming ground, and 2 new booming grounds were added (table 11). During 1980, there were 5 booming grounds with 62 male prairie chicken and 4 hybrids (table 10 and figure 2).

The area of occupied habitat increased slowly as did the population of prairie grouse and the number of active display grounds from 1961 to 1970. In 1961, 3 booming grounds were active in the West Central District, and 1 booming ground was active in each of the South East and North East Districts. The occupied habitat was 10.5 mi² (27.2 km²) with 6,720 acres (2720 ha) (table 12). In 1970 (year 10), 6 display grounds were known in the West Central District, 1 booming ground was known in the South East District, and 2 display grounds were known in the North East District. The occupied habitat had not increased past 16.0 mi² (41.4 km²) with 10,240 acres (4144 ha) (table 12).

The area of occupied habitat greatly increased as did the population of prairie grouse and the number of active display grounds from 1971 to 1980. In 1971, 7 display grounds were active in the West Central District, and 3 display grounds were active in the North East District with 19 male prairie chicken, 29 male sharptailed grouse, and 4 hybrid. Display grounds in the South East District were not censused during 1971. The occupied habitat was 28.0 mi² (72.5 km²) with 17,920 acres (7252 ha) (table 12).

In 1975 (year 15), 14 display grounds were active in the West Central District, 8 display grounds were active in the South East District, and 5 display grounds were active in the North East District with 143 male prairie chicken, 53 male sharptailed grouse, and 20 hybrid. The occupied habitat was 51.0 mi² (132.1 km²) with 32,640 acres (13,209 ha) (table 12).

In 1980 (year 20), 27 display grounds were active in the West Central District, 14 display grounds were active in the South East District, and 8 display grounds were active in the North East District with 411 male prairie chicken, 190 male sharptailed grouse, and 17 hybrid. The occupied habitat had increased to 75.0 mi² (194.3 km²) with 48,000 acres (19,426 ha). The potential habitat was 100.1 mi² (259.3 km²) with 64,064 acres (25,927 ha). Which means that 25.0 mi² (64.8 km²) with 16,000 acres (6,475 ha) remained unoccupied in 1980 and would have been available for future expansion.

Unfortunately in 1979, the grazing management was drastically changed to multiple pastures grazed one time and one of the pastures deferred until late season. The number of pastures grazed two times per year were rapidly reduced to zero shortly after 1979. This major change in grazing management practices terminated the 10 year (1971 to 1980) period with encouraging increases in prairie chicken population. After these changes in grazing management, the prairie chicken population has had wide irregular fluctuations with a decreasing trend.

Results for Nesting Activity

Female prairie chicken visit the booming ground several times before she submits to copulate with the male of her choosing, which is not always the dominant male. The hen had previously selected a nest site with good visual obstruction cover. After mating, she finishes building the ground nest. The first egg is laid in about 3 days (1 to 5 days), followed by one egg per day, until a full clutch with a mean of 13 eggs (11 to 16 eggs) (table 13). Incubation starts after all the eggs are laid and usually takes 25 days (23 to 27 days). The hen leaves the nest for brief periods to feed but spends most of the time on the nest, the male does not help.

Two nests were located by the cable-chain drag, 1 nest was located incidentally with a vehicle, by flushing the hen digging a nest scrape, 5 nests were located by the dogs, a dog was used to relocate a nest that a curious deer had removed the marker flag, and 3 nests were located by private land owners that reported the information.

The mean distance of the nest sites to the nearest display grounds was 0.80 miles (1.3 km) (table 13). However, the hen may not have mated on the nearest display ground. Nine nest sites were located in native vegetation of the midland tall grass prairie community with switchgrass a dominant species. The immediate nest sites were

characteristically completely covered by vegetation. The sides and top were very dense residual and growing vegetation. The mean 100% VOM at nest center was 2.85 dm (11.2 in). Some nest sites had a definable hole in the vegetation for the hen to pass in or out. Most of the nest sites had an elliptical shape with the mean dimensions of 1.8 X 2.1 ft (0.55 X 0.64 m) and an area of 2.68 ft² (0.25 m²). All of the nest sites were located on relatively level topography, with slopes of 0% to 5%, and the aspect was mostly east or west (table 14).

The surrounding nest cover had a mean 100% VOM of 2.5 dm (9.9 in). The distance to short vegetation of less than 1 dm (3.9 in) was categorized into narrow (<10 ft) (<3.0 m), medium (to 50 ft) (to 15.2 m), and wide (>50 ft) (>15.2 m) cover (table 14). Four nest sites were in narrow cover with a mean of 5.3 ft (1.6 m) to short vegetation. Two of these nests were depredated, and two of the nests had been located during the early stages and were abandoned. The one nest in medium cover at 12 ft (3.7 m) to short vegetation was successful in a private pasture with the full clutch of 13 eggs hatched. Four nest sites were in wide cover with a mean of 100 ft (30.5 m) to short vegetation. One of the nests was abandoned, two of the nests had partial success with 7 of 12 eggs hatched on one nest, and 14 of 16 eggs hatched on the other nest. And on the fourth nest, a full clutch of 11 eggs hatched (tables 13 and 14).

Two nest sites were located in alfalfa cropland. Alfalfa produces very appealing nest cover when it has not been cut late the previous fall. The problem of using alfalfa for prairie grouse nest cover is that the optimum time to cut the first crop of alfalfa hay coincides with egg incubation stages. One of the nests had only 2 eggs and was disturbed during early stages of egg laying, the hen was flushed, but the nest was abandoned. The hen on the other nest was incubating 13 eggs and was killed by the swather (table 13). Providing, at no cost, flushing bars for swathers and mowing equipment to agricultural producers may save some incubating hens.

Results for Brooding Activity

Prairie chicken chicks have an “egg tooth” which is a hard white growth on the end of their bill to help them break the eggshell from inside. It disappears soon after hatching. The chicks are precocial, they are covered with down, the eyes are open, they can walk and feed themselves as soon as they are dry. Most of the first day is spent on or near the nest site. The chicks eat a high protein diet of mostly insects and grow very fast. They are capable

of short flights at 7 to 10 days old. At 90 days old, the young cannot easily be distinguished from adult plumage, except the chicks are still lighter weight.

The estimated age of the chicks was based on the relative body size in relation to an adult bird and the stage of plumage development (table 15). At the time, the research to identify the stages for aging young prairie grouse was for birds in the hand, not for field observations.

The prairie chicken brood search was conducted for 6 years from mid June to mid September. The trained bird dogs located 41 broods and 14 broods were located by vehicle transects. One hybrid chick with a prairie chicken hen was located (table 17).

The prairie chicken brood size tended to decrease with time. The mean prairie chicken completed clutch size was 13 ± 1.67 eggs. About 50% of the nests hatch some eggs. The mean number of eggs that hatched from successful nests was 12 ± 1.63 eggs. The brood size in mid July was 10 chicks, by mid August the brood size was 7.2 chicks, and by mid September the brood size had decreased to 6.8 chicks (table 16). The high percent of losses appears to occur early after hatch. From a full clutch of eggs in a nest to mid September, the hens had been able to save about 50% of their chicks, which seems to be a remarkable accomplishment. During a biweekly period, the age of young birds had a wide spread in age of about 30 days from youngest to oldest.

Prairie chicken broods were located in a wide variety of habitats with 45% in shrubs, 42% in grass, and 13% in forbs (table 17). Sixteen (29%) broods were located in the upland grass mixed prairie communities with 75% in lead plant, 19% in spiraea, and 6% in buckbrush. Twenty four (44%) broods were located in the midland tall grass prairie communities with 58% in grasses, mostly switchgrass, along with little bluestem, cordgrass, and big bluestem, 29% in shrubs, mostly willow, along with lead plant and buckbrush, and 13% in sweet clover and grass. Ten (18%) broods were located in the lowland sedge meadow communities with 80% in woolly sedge and 20% in willow. Five (9%) broods were located in cropland with perennial plants, with 80% in alfalfa, one brood was in mowed alfalfa, and 20% in smooth brome grass unmowed hay field (table 17).

Prairie chicken broods were very mobile and travel over a large area and use several habitat types. Areas of shorter vegetation that had been mowed or

grazed were used as feeding areas. The adjacent areas of dense residual and growing vegetation were used for escape cover and loafing. Broods usually used areas that had a high amount of shrubs and forbs. These areas usually provided good canopy cover and relatively open understories.

The height-density pole was used to evaluate the quality of six prairie grouse brood habitat sites (tables 18 and 19). The upland shrub site had a mean 100% VOM of 1.6 dm (6.3 in) with 65% of the reading at or above 1.5 dm. The two midland grass sites had mean 100% VOM of 1.9 dm (7.5 in) and 2.3 dm (9.1 in) with 97% and 100% of the readings at or above 1.5 dm. The midland grass-shrub site had a mean 100% VOM of 2.4 dm (9.5 in) with 95% of the readings at or above 1.5 dm. The lowland sedge-grass site had a mean 100% VOM of 1.8 dm (7.1 in) with 85% of the readings at or above 1.5 dm. The lowland sedge-shrub site had a mean 100% VOM of 1.9 dm (7.5 in) with 95% of the readings at or above 1.5 dm (tables 18 and 19). Prairie grouse hens selected very good concealment cover for their broods.

Results for Roosting Activity

A very high percentage of the life of prairie grouse is spent on night and dry roosts. The number of night roosts located with and without a bird was 236, and the number of day roosts located with a bird was 39.

Several night roosts were located during the day without a bird present. I did not know how to tell if these night roosts had been occupied by a prairie chicken or a sharptailed grouse. When I was in the early stages of this study, Leo Kirsch told me there was a simple technique to separate prairie grouse feces; prairie chicken have a sweet taste and sharptailed grouse have a bitter taste. To eliminate any possibility for identification error, this study became a prairie grouse roost study, rather than two separate species studies.

The prairie grouse night roost sites were primarily located in the midland switchgrass and the lowland woolly sedge communities during spring, summer, and fall (table 20). The switchgrass portion of the midland tall grass prairie was more important for night roost sites than the upper portion with little bluestem and big bluestem.

The habitat quality of 27 night roost sites were evaluated with the height-density pole during spring and fall. The mean 100% VOM during the

spring was 1.6 dm (6.3 in) and during the fall was 2.0 dm (7.9 in). The habitat selected for night roost sites in the switchgrass and woolly sedge communities provided very good concealment cover for prairie grouse.

Prairie grouse shift from grassland habitat to cropland habitat during the fall to use spilled grain for food. The night roost sites also shift to be located near the planted tree shelterbelts and the volunteer willow, cottonwood, and aspen located near cropland (table 20). The trees provide some protection from winter weather and the deeper snow drifts develop on the lee side of these trees. The snow drifts were used by the prairie grouse to make snow burrows. Most of the snow burrows were located in about 12 inches (30.5 cm) of snow. Snow burrows reduce body heat loss compared to a bird sitting on top of the snow surrounded by dense standing grass cover.

Prairie grouse activities between morning and evening feeding periods was considered to be loafing. Prairie grouse loafing activities are when the birds slowly move around by spending a few minutes in one spot and then move a short distance to the next spot seemingly without purpose or direction. Some of the stops last longer than 30 minutes in one spot before moving again. The long stop spots were considered to be day roosts. Some day roosts were occupied for more than 2 hours but most were occupied for 30 minutes to one hour.

The prairie grouse day roost sites were primarily in the midland switchgrass habitat during spring and fall. The day roost sites were located in the upland and lowland during summer (table 21). The summer day roost sites were associated with shrubs. The shrubs provide good canopy cover and shade from the hot sun. There were no day roost sites located during the winter. The prairie grouse were presumed to not spend more than 30 minutes in one spot while day loafing during winter.

The habitat quality of 15 day roost sites were evaluated with the height-density pole. The mean 100% VOM was 1.5 dm (5.9 in). However, the day roost sites did not have good concealment cover on all sides. The day roost sites had one side open. The mean 100% VOM for the three good cover sides was 1.9 dm (7.5 in). The day roost sites had good concealment cover so the bird was protected on the sides and back and the resting bird could watch for possible danger by facing out on the low side which presented no obstacles for rapid egress if the situation called for immediate escape activity.

Prairie grouse require good concealment cover for night roosts during spring, summer, and fall and need snow drifts that are about 12 inches (30.5 cm) deep during winter. The day roost sites are part of loafing activity with protective cover that has a vantage point to watch for danger.

Results for Winter Activity

A mean of 1,346 miles of road transect was traveled per winter that located a mean of 733 male and female prairie grouse. A mean of 93 miles were walked with dogs covering 8,790 acres per winter that located a mean of 1,026 male and female prairie grouse. The two methods located a mean of 1,759 prairie grouse per winter which included repeat sightings.

The prairie grouse gathered on the display grounds during October. They determined or reestablished the pecking order through mock skirmishes and redeveloped strong bonds among the male and female members of these small display ground flocks. When the weather became colder, the small display ground flocks joined with other small flocks of their locale and formed larger flocks with fairly loose bonds. Traditionally, flocks with greater than 60 birds have been called a pack.

During the winter period, prairie grouse flocks were very mobile and would travel several miles. Their activity shifted from using grassland habitats to using cropland habitats and adjacent tree shelterbelts. The birds remained in close association with the cropland and related shelterbelts until spring.

A typical winter day for a small flock of prairie grouse began with the birds emerging from snow burrows shortly after dawn. The snow burrows were located in snow drifts about 12 inches deep that had formed by the protection provided by cropland shelterbelts, old homestead planted tree claims, or clumps of volunteer trees. The birds apparently flew into the roosting area, there were no tracks that lead into the burrow sites. The birds dig a tunnel in the snow that was usually one to three or more feet long. A small cavity that formed the night roost was located at the end of the tunnel. Usually there was only one bird per burrow and each burrow was used one time. A cluster of a small group of 3 or 4 burrows were located in the same area. At dawn, the birds burst through the snow above the roost cavity or they dug a short exit tunnel and usually walk a short distance from the burrows, there were usually tracks leading away from the burrow. They group together at a staging area and then flew to a feeding area of fields

with harvested corn or sunflowers. Some years, the sunflowers had not dried enough to be harvest and remained standing. At least one of the birds needed to know how to land on the standing sunflower plant and ride it down to the ground. The other birds took turns feeding from the downed sunflower head. On the harvested fields, birds would search for spilled grain and crop residue along with consuming seeds from weedy plant species. If the crop residue was being used for fall cattle feed, the birds would peck out the undigested grain and seeds from the cattle manure. Prairie grouse are capable of scratching in the snow to get to spilled grain. No scratch areas were found that went deeper than 3 inches. Most of the scratch areas were less than one inch deep. Birds would fly from the field into the adjacent trees and feed on buds daily. The morning intensive feeding period would be completed in about 30 minutes. The birds would spend the rest of the day loafing. The loafing period would be spent by slowly moving around, pecking at food items, squatting down for a short period in one spot, and then again slowly moving around. On some days the large flock would remain together. Other days, small flocks would leave and loaf in different areas. One small flock repeatedly returned to the same area where frozen piles of cow manure had concentrated. The birds were very difficult to distinguish from the frozen piles of manure. About 1 hour to ½ hour before sundown, the birds would move back to an area of cropland and begin the evening intensive feeding period. Tree buds were usually not eaten during the evening. At dusk, the birds would leave the feeding area and fly to a new area near trees to make snow burrows for the night roost.

The observed food items included spilled and unharvested corn and sunflowers, tree buds from cottonwood, aspen, green ash, and boxelder, and fruits from green ash and Russian olive. Birds pecked at grasses, forbs, and weeds that retained seeds at their height. Feces collected from snow burrow night roosts contain rose hip seeds which was assumed to be used as grit as there are no natural gravel deposits available in the sandhills region. An unexpected item found in winter feces was grasshopper parts which the birds collected from hay stacks and round bales intended for livestock feed. The birds also collected pieces from green leaves of monocots and dicots, grasses and alfalfa, from the harvested hay. The need for high energy winter food by prairie grouse is critical. The birds must survive the winter and be healthy during the spring in order to reproduce successfully.

Results for Prairie Chicken Habitat Usage

The Sandhills region was comprised of eleven habitat types grouped into four habitat associations (table 22). The largest habitat association was the Hummocky Sandhills that consisted of 65,494 acres, and was 50.16% of the Sandhills region. It was comprised of the Upland mixed grass prairie habitat type that consisted of 34,389 acres, 26.34%, with blue grama, needle and thread, and upland sedge; the Midland tall grass prairie habitat type that consisted of 16,558 acres, 12.68% with little bluestem, big bluestem, and switchgrass; the Lowland sedge meadow habitat type that consisted of 12,737 acres, 9.76% with woolly sedge, northern reed, and baltic rush; and the Cropland habitat type that consisted of 1,810 acres, 1.39% with replacement vegetation.

The second habitat association was the Deltaic Plain that consisted of 38,761 acres, and was 29.69% of the Sandhills region. It was comprised of the Midland tall grass prairie habitat type that consisted of 14,476 acres, 11.09%, with little bluestem, big bluestem, and Indian grass; the Lowland sedge meadow habitat type that consisted of 5,387 acres, 4.13% with woolly sedge, northern reed, and lowland sedge; and the Cropland habitat type that consisted of 18,898 acres, 14.47% with replacement vegetation.

The third habitat association was the Choppy Sandhills that consisted of 19,170 acres, and was 14.68% of the Sandhills region. It was comprised of the Upland Woodland grove and savanna habitat type that consisted of 12,269 acres, 9.40%, with bur oak, quaking aspen, and green ash; and the Open Grassland thin mixed grass prairie habitat type that consisted of 6,901 acres, 5.29% with blue grama, upland sedge, and sand dropseed.

The smallest habitat association was the River Terrace that consisted of 7,135 acres, and was 5.46% of the Sandhills region. It was comprised of the Riparian Forest habitat type that consisted of 5,710 acres, 4.37% with basswood, American elm, green ash, and box elder; and the Cropland habitat type that consisted of 1,425 acres, 1.09% with replacement vegetation.

Transportation Routes have been constructed across the Sandhills region. Gravel Roads have a total length of 112 miles with 679 acres of right of way, 0.52%; Railroads have a total of 17.5 miles of track with 106 acres of right of way, 0.08%;

and Asphalt Roads have a total length of 13 miles with 79 acres of right of way, 0.06%.

Habitat usage by prairie chicken during four seasonal periods was determined by the habitat use index (% of bird locations/% of study area). The spring activity period occurred over 2.5 months from 1 April to 15 June with 3,642 observations of prairie chicken performing seasonal activities. The habitat use index for the Hummocky Sandhills was high at 1.89, for the Deltaic Plain was low at 0.17, and was zero for the Choppy Sandhills and River Terrace. The habitat use index for the Upland mixed grass prairie was at 5.49 of the Deltaic Plain, and for the Midland tall grass prairie was at 3.38 and for the Upland mixed grass prairie was at 1.64 of the Hummocky Sandhills. The prairie chicken were still feeding on the cropland area of the Hummocky Sandhills was at 0.97 and of the Deltaic Plain was at 0.96. The Lowland sedge meadow was at 0.76 of the Hummocky Sandhills and the Midland tall grass prairie was at 0.40 and the Lowland sedge meadow was at 0.14 of the Deltaic Plain which were used for concealment cover (table 23).

The summer activity period occurred over 2.5 months from 16 June to 31 August with 638 observations of prairie chicken performing seasonal activities. The habitat use index for the Hummocky Sandhills was high at 1.78, for the Deltaic Plain was low at 0.35, and was zero for the Choppy Sandhills and River Terrace. The habitat use index for the Midland tall grass prairie was at 3.34, the Lowland sedge meadow was at 1.27, and the Upland mixed grass prairie was at 1.18 of the Hummocky Sandhills which were used for concealment cover and protection from the hot sun by the males and for nest and brood cover by the hens. The cropland area was highly used at 2.65 of the Hummocky Sandhills by hens for cover and feeding of broods. The Lowland sedge meadow was at 0.49, the Midland tall grass prairie was at 0.34, and the cropland area was at 0.41 of the Deltaic Plain which were used for concealment, protection from the hot sun, and brood cover and feeding areas at a lesser extend than the same activities on the Hummocky Sandhills (table 23).

The Fall activity period occurred over 2.5 months from 1 September to 15 November with 780 observations of prairie chicken performing seasonal activities. The habitat use index for the Deltaic Plain was high at 1.81, for the Hummocky Sandhills was moderate at 0.73, and was zero for the Choppy Sandhills and River Terrace. The Fall period had several changes with a shift from grassland habitats to cropland habitats, the hens leave her brood which

brake up and disperse, and adult and juvenile birds gather at fall display grounds forming small winter flocks. The greatest habitat use index was the Upland mixed grass prairie at 1897.44, and the Lowland sedge meadow at 5.90 of the Deltaic Plain primarily because of the large quantity of buckbrush on the Upland which was used by males and broods for concealment cover, shade, and the ripe berries for food. The cropland area of the Hummocky Sandhills had a very high index at 11.12 which was used by broods for cover and food. The small display ground flocks of prairie chicken used the cropland for food earlier than sharp-tailed grouse. The Upland mixed grass prairie was at 0.55, the Midland tall grass prairie was at 0.42, and the Lowland sedge meadow was at 0.17 of the Hummocky Sandhills and Midland tall grass prairie was at 0.94 of the Deltaic Plain which were used for shade, and concealment cover (table 23).

The Winter activity period occurred over a long 4.5 months from 16 November to 31 March with 3,524 observations of prairie chicken performing seasonal activities. The habitat use index for the Deltaic Plain was high at 2.58, for the Hummocky Sandhills was low at 0.36, and was zero for the Choppy Sandhills and River Terrace. The habitat use index for the Upland mixed grass prairie with buckbrush was at 295.12 of the Deltaic Plain which was used by the small display ground flocks for concealment cover and the berries for food. The shift from grassland habitat to cropland habitat and adjacent tree shelterbelts had been completed. The high index for cropland area was at 6.11 and for shelterbelts was 55.81 for the Hummocky Sandhills and for cropland was 3.68 and shelterbelts was at 5.56 for the Deltaic Plain which indicates the importance of agricultural food sources during the winter. The Midland tall grass prairie was at 0.99 and the Lowland sedge meadow was at 0.89 of the Deltaic Plain and the Midland tall grass prairie was at 0.34, the Upland mixed shrubs was at 0.14, and the Lowland sedge meadow was at 0.01 of the Hummocky Sandhills which were used for loafing areas between the morning and evening feeding periods on the cropland areas (table 23).

The gravel roads had high use indices during the fall at 7.89 and winter at 1.04 which were used for grit, for spilled grain moved from field to storage, and for dust baths. Rose hip seeds were used for grit during every month of the year, but were more difficult to locate during fall and winter, thus needing to be supplemented with gravel grit during fall and winter (table 23).

Prairie chicken used the grassland habitats of the Hummocky Sandhills during the spring and summer and moved to the cropland habitat and adjacent planted tree shelterbelts and volunteer trees of the Hummocky Sandhills and Deltaic Plain during fall and winter. Prairie chicken did not use the habitat types of the Choppy Sandhills or River Terrace.

Habitat usage by prairie chicken during three critical activities of courtship, nesting, and brood rearing were determined by the habitat use index (% of bird locations/% of study area). The critical courtship and mating activity is performed on communal display grounds (booming grounds) had 228 observations. Each display ground is anchored on the Upland mixed grass prairie with the vegetation grazed with an habitat use index value of 131.58 for the Deltaic Plain and 1.90 for the Hummocky Sandhills. The Midland tall grass prairie was used by males as courtship territories if mowed the previous year and used as concealment cover by males and females if not mowed with habitat use index values of 2.56 for the Hummocky Sandhills and 0.40 for the Deltaic Plain. The Lowland sedge meadow is occasionally used by males as courtship territories if mowed the previous year and used primarily as concealment cover by males and females if not mowed with habitat use index values of 0.99 for the Hummocky Sandhills and 0.32 for the Deltaic Plain (table 24).

The critical nesting activity was performed solely by the females with no help from the males had 11 observations. Each nest site is placed in very good concealment cover with high visual obstruction. The habitat use index value was high at 6.45 for the switchgrass portion of the Midland tall grass prairie of the Hummocky Sandhills. The habitat use index value was high at 1.60 for alfalfa cropland of the Deltaic Plain. Unfortunately, the optimum cutting time for the first hay crop coincides with egg incubation time resulting in unsuccessful nesting activity (table 24).

The critical brood rearing activity was performed solely by the females with no help from the males had 54 observations. All broods that were accompanied by a hen used a wide variety of habitats for concealment cover and feeding. Usually the brooding habitat had an abundance of shrubs and forbs that provided good canopy cover and open understory. The greatest habitat use index was the Midland tall grass prairie at 3.12, the Upland mixed shrubs at 1.27, the perennial plant cropland with alfalfa or smooth brome grass at 1.14, and the

Lowland sedge meadow with willows at 1.12 of the Hummocky Sandhills. Brood habitat use also included the Lowland sedge meadow with willows at 0.62, the perennial plant cropland with alfalfa at 0.56, and the Midland tall grass prairie with spiraea, or lead plant at 0.46 of the Deltaic Plain (table 24).

A very high percentage of the life of prairie grouse is spent on night and day roosts. About the only time a fox or coyote can catch a prairie grouse is on the night roost. The habitat selected for night and day roosts is critical to the survival of the prairie grouse. Night roosts with or without a bird present were observed 236 times. Day roosts with a bird present were observed 39 times.

The greatest habitat use index values was for night roosts on the Midland tall grass prairie with switchgrass of the Hummocky Sandhills during spring at 4.57, during summer at 6.12, during fall at 5.70, and during the winter at 1.94. High habitat use index values was for the Lowland sedge meadows of the Hummocky Sandhills during spring at 3.64, during summer at 2.30, and during fall at 1.33. Habitat use index value for night roosts in snow drifts during winter that extended into the cropland was at 2.61, and in snowdrifts near shelterbelts was at 12.41 (table 25).

The greatest habitat use index values was for day roosts on Midland tall grass prairie with switchgrass on the Hummocky Sandhills during spring at 7.10, and during fall at 7.89, and on Upland mix grass with shrubs during summer at 3.16, and on Lowland sedge meadow with shrubs during summer at 1.71 of the Hummocky Sandhills. No day roosts observed during winter (table 25).

Discussion

Long term survival of prairie chicken in the Sandhills region depends on the availability of short stature habitat for courtship activities, good concealment cover for nesting, brooding, roosting, and escaping activities, and agricultural commodities for winter food. The quality of the grassland habitats is greatly affected by the type of grazing management implemented.

The 6 month seasonlong treatment resulted in a mean 100% VOM of the switchgrass zone at 1.3 dm (5.1 in) with 43% readings at or above 1.5 dm during spring, 13% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly

increased with Kentucky bluegrass, and decreased with cool and warm season native grasses.

The deferred grazing treatment resulted in a mean 100% VOM of the switchgrass zone at 1.6 dm (6.3 in) with 62% readings at or above 1.5 dm during spring, 20% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly increased with Kentucky bluegrass, and decreased with switchgrass, warm and cool season native grasses, and upland sedges.

The two pasture switchback strategy resulted in a mean 100% VOM of the switchgrass zone at 1.7 dm (6.7 in) with 63% readings at or above 1.5 dm during spring, 30% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly decreased with switchgrass, warm and cool season native grasses, and upland sedges.

The allotments with multiple pastures grazed two times per year resulted in a mean 100% VOM of the switchgrass zone at 2.0 dm (7.9 in) with 78% readings at or above 1.5 dm during spring, 32% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly increased with switchgrass, lowland sedges, warm and cool season native grasses, upland sedges, and total basal cover.

During the 28 year period that all 56 allotments were grazed with 8 month or 6 month seasonlong, the male prairie chicken population remained low with probably no more than 23 males. During a 3 year period that 39% of the lands was managed with multiple pastures grazed one time per year with one pasture deferred to late season, the census documented 19 male prairie chicken on the spring after the third year. During the next 3 years, 10% of the land was grazed two times per year, the number of male prairie chicken increased to 78. During the next 5 years the quantity of land managed with grazing two times increased from 26% to 54% of the land and the male prairie chicken census increased to 338 with the increase continuing for one additional year, with the peak prairie chicken census at 411 males. Then grazing management was changed back to multiple pastures grazed one time per year with one pasture deferred to late season and the pastures grazed two times per year were decreased to zero causing the prairie chicken

population to have wide irregular fluctuations with a declining trend. This drastic change in grazing management effectively terminated the 10 year period with encouraging increases in prairie chicken numbers.

During this 10 year improvement period, the prairie chicken population increased from 19 to 411 males, the quantity of land managed with two grazing periods per year increased from 10% to 54%, which greatly increased the quantity and quality of the available concealment cover. The mean 100% VOM at 1.5 dm (5.9 in) was considered to be the minimum for good concealment cover.

During the period of increasing prairie chicken population, the concealment cover used for nesting activities had a mean 100% VOM at 2.5 dm (9.9 in). The concealment cover used for brooding activities with upland shrubs had a 100% VOM at 1.6 dm (6.3 in), with midland grass had 100% VOM at 1.9 dm (7.5 in) and 2.3 dm (9.1 in), with midland shrubs had a 100% VOM at 2.4 dm (9.5 in), with lowland grass had a 100% VOM at 1.8 dm (7.1 in), and with lowland shrubs had a 100% VOM at 1.9 dm (7.5 in). The concealment cover used for night roosting activities had a mean 100% VOM at 1.6 dm (6.3 in) during spring and at 2.0 dm (7.9 in) during fall.

During the period with declining prairie chicken population, the available concealment cover would have decreasing quantity and quality that resulted after the drastic changes to grazing management practices with multiple pastures grazed one time per year and one pasture deferred until late season. The type of grazing management implemented affects the quality of grassland habitat available to grassland wildlife.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.



Prairie Chicken, Male. Photo by Al Smith



Hybrid (Prairie Chicken X Sharp-tailed Grouse), Male. Photo by Ed Bry

Table 1. Active male spring census of Prairie Chicken on Booming Grounds.

Booming Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1	7		10	16	17		18	14	13	28	31	20
2				4	4		4	3	3	5	2	2
3				3	3	8	3	3	1	1	2	1
3 Sat							1		1		1	2
5		1	1				4	1	4		2	1
6				5			1	5	11	16	16	10
8 W				11	11		11	10	11		8	17
8 E										12	6	8
9			3		2		1	3	4	13	19	16
11				5	7		5	1	2	2	2	3
12			5	8	15	2	7	8	9	11	8	7
16				2	5	9	3			11	19	22
17				1	1	1	1	11	19	13	3	9
19					6	11	14	14	16	6	9	11
21						2	2		1		9	4
22						7	7	6	6	2		
23						2					3	4
24						8	9	11	22	18	19	28
25						8	14	14	16	11	8	15
27							10	11	16	17	44	48
29								2	2		11	10
34									1		8	8
35											5	6
36											9	23
37											7	8
39							1	2	1		6	13
40											4	11
43								3	1		14	23
46 E										2	3	3
46 W												8
48										4	2	5
49												6
PC Males	7	1	19	55	71	58	116	122	160	172	280	352

Table 2. Active male spring census of Prairie Chicken on Mixed Display Grounds.

Mixed Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
7				7	5	3	6	12	7	5	14	4
13 E					3				2	3	6	4
13 W						11	5					2
15				2			1			1		3
26						3	6	9	12	9	10	10
28							5	4	5	4	4	6
30 N								1		1	1	
30 S								1	3		10	10
42											3	8
44											1	1
45										2	8	2
PC Males				9	8	17	23	27	29	25	57	50

Table 3. Active male spring census of Prairie Chicken on Dancing Grounds.

Dancing Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
4		2					1				1	7
4 S												2
10				4				1				
14					2	3						
18					8		1					
20							2					
PC Males		2		4	10	3	4	1			1	9

Table 4. Total active male spring census of Prairie Chicken.

Type Display Ground	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Booming	7	1	19	55	71	58	116	122	160	172	280	352
Mixed				9	8	17	23	27	29	25	57	50
Dancing		2		4	10	3	4	1			1	9
Total PC Males	7	3	19	68	89	78	143	150	189	197	338	411

Table 5. Active male spring census of Hybrid Grouse with Prairie Chicken on Display Grounds.

Display Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1				8			5	6	1	1	1	1
6									1			
7							1		1		1	2
9					1							
11								1				
13 E											1	
13 W							2					
16												1
17									1			
22								2				
24							1	2		1	2	1
25								1		1		
26							6	3	1	1	2	
27							1				2	3
28											2	
43												2
46 E											1	
Hybrid Males				8	1		16	15	5	4	12	10

Figure 1. Daily and weekly percentage of male [♂] and female [♀] prairie chicken [PC] present on the display grounds—1975-1980.

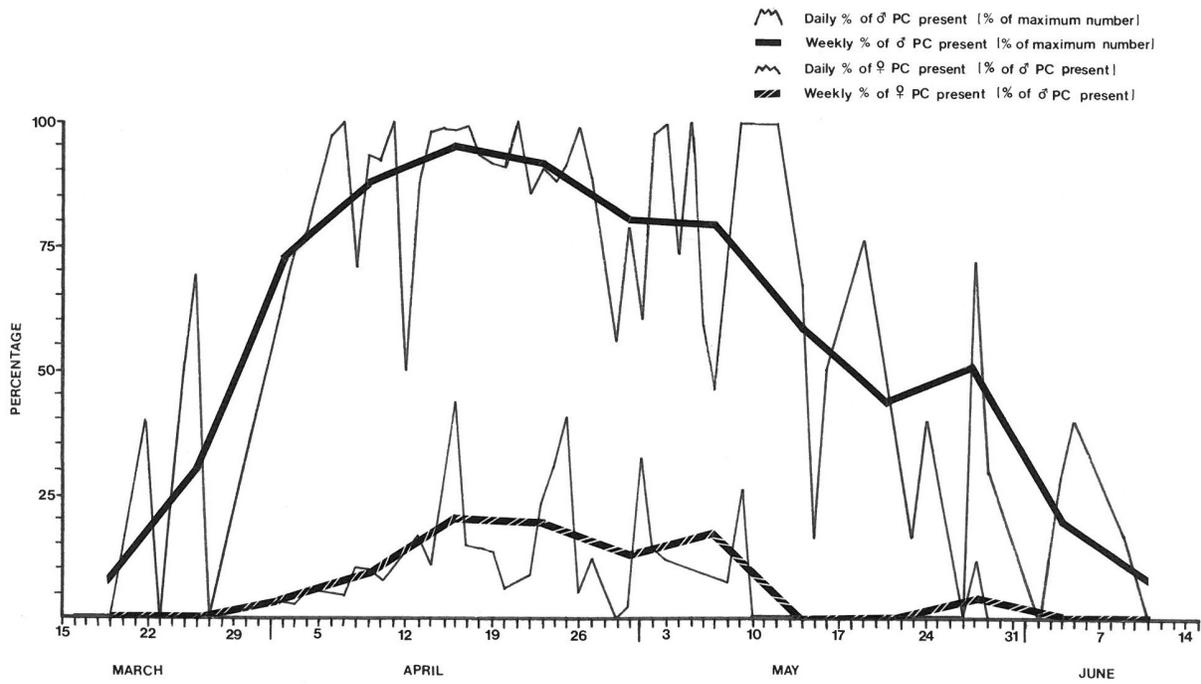


FIGURE 2. PRAIRIE GROUSE DISPLAY GROUNDS ON THE SHEYENNE NATIONAL GRASSLANDS-1980

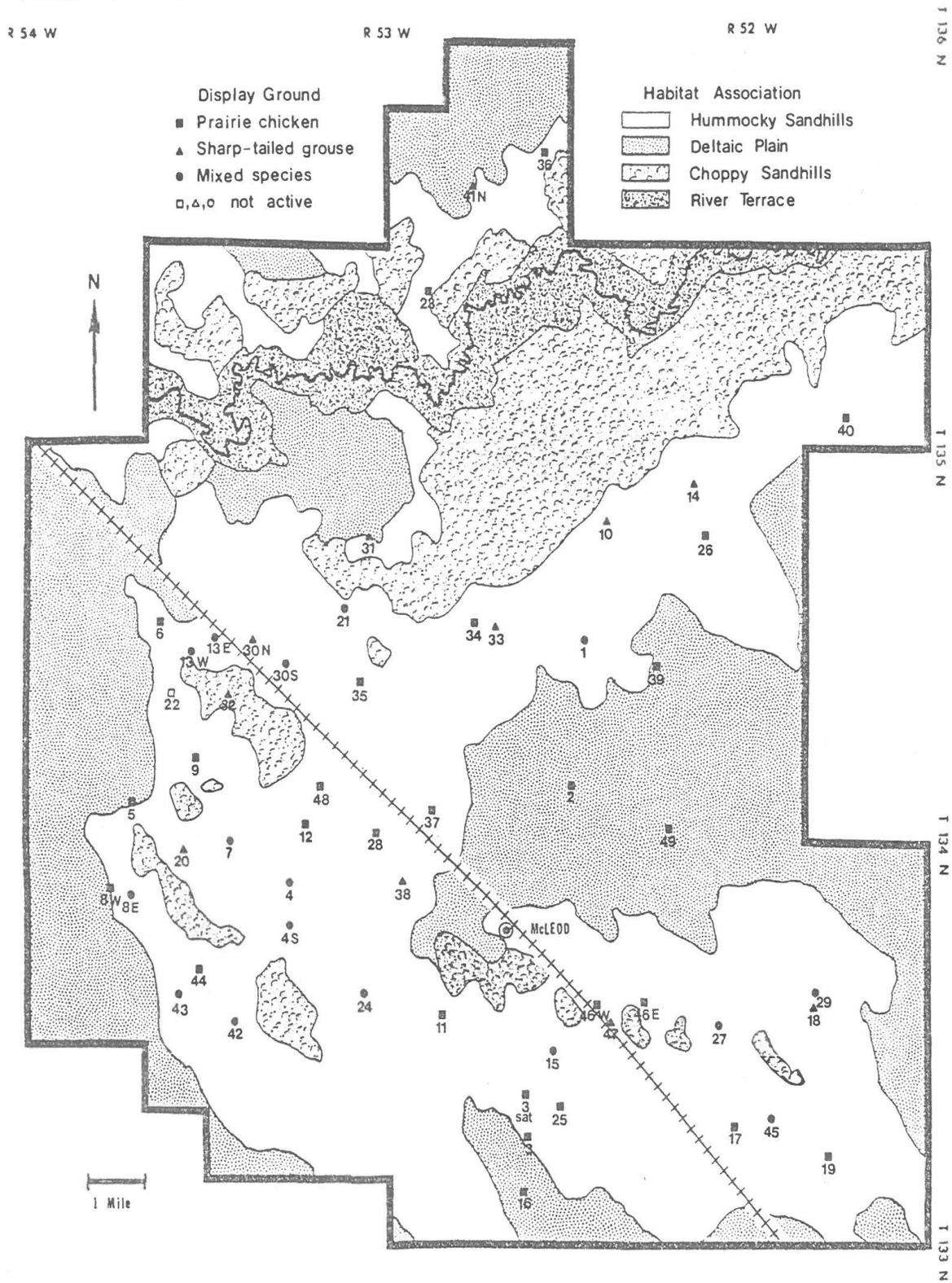


Table 6. Movement rate of spring Prairie Chicken Booming Grounds

Booming Ground Number	Years Censused #	Different Locations #	Movement Rate %	Distance Moved mi	Size Movement Zone mi X mi	Area Movement Zone acre
1	11	8	72.7	0.50	0.52 X 0.44	147
2	8	7	87.5	0.71	0.71 X 0.70	320
3	8	7	87.5	1.24	1.20 X 0.46	352
3 Sat	5	5	100.0	0.73	0.98 X 0.73	461
5	13	9	69.2	1.78	0.77 X 0.71	352
6	8	5	62.5	0.66	0.63 X 0.28	115
8 W	8	5	62.5	0.95	0.95 X 0.71	429
8 E	3	2	66.7	0.34	0.28 X 0.17	32
9	7	5	71.4	0.52	0.65 X 0.30	128
11	7	6	85.7	1.26	1.26 X 0.54	435
12	10	1	10.0	0.11	0.11 X 0.09	6
16	5	5	100.0	0.71	0.56 X 0.40	141
17	9	6	66.7	0.71	0.84 X 0.59	320
19	8	4	50.0	0.41	0.59 X 0.59	224
21	5	4	80.0	0.63	0.65 X 0.27	115
22	5	5	100.0	0.29	0.37 X 0.29	70
23	3	3	100.0	1.51	1.58 X 0.28	282
24	7	4	57.1	0.46	0.34 X 0.34	77
25	7	2	28.6	0.12	0.20 X 0.10	13
27	6	4	66.7	0.26	0.27 X 0.16	26
29	4	2	50.0	0.34	0.29 X 0.27	51
34	3	2	66.7	0.85	0.91 X 0.18	102
35	2	1	0.0	0.0		
36	2	1	0.0	0.0		
37	2	1	0.0	0.0		
39	5	3	60.0	0.91	0.89 X 0.59	339
40	2	2	100.0	0.28	0.30 X 0.17	32
43	4	4	100.0	1.33	1.09 X 0.83	576
46 E	3	2	66.7	0.28	0.28 X 0.16	26
46 W	1	1	0.0	0.0		
48	3	2	66.7	0.26	0.26 X 0.05	6
49	1	1	0.0	0.0		
Mean N=26	6.0	4.4	74.0	0.69	0.67 X 0.40	199

Table 7. Movement rate of spring Prairie Grouse Mixed Display Grounds.

Mixed Ground Number	Years Censused #	Different Locations #	Movement Rate %	Distance Moved mi	Size Movement Zone mi X mi	Area Movement Zone acre
7	10	3	30.0	0.18	0.17 X 0.13	13
13 E	8	2	25.0	0.12	0.22 X 0.09	13
13 W	3	2	66.7	0.18	0.15 X 0.13	13
15	5	4	80.0	0.71	0.70 X 0.34	154
26	7	5	71.4	0.34	0.40 X 0.27	70
28	6	3	50.0	0.13	0.13 X 0.04	6
30 N	4	1	0.0	0.0		
30 S	4	4	100.0	0.63	0.65 X 0.17	70
42	2	2	100.0	0.46	0.39 X 0.27	70
44	2	2	100.0	0.54	0.42 X 0.40	109
45	3	2	66.7	0.17	0.15 X 0.15	13
Mean N=10	5.0	2.9	69.0	0.35	0.34 X 0.20	53

Table 8. Population expansion of Prairie Chicken on the West Central District.

Year	Active Display Grounds		Active Males	
	PC	Mixed	PC	Hy
1961-1969	5	0	5	1
1970-1974	9	3	24	
1975	13	0	66	4
1976	12	1	66	5
1977	11	3	88	2
1978	9	3	91	1
1979	14	6	157	6
1980	15	6	180	5

Table 9. Population expansion of Prairie Chicken on the South East District.

Year	Active Display Grounds		Active Males	
	PC	Mixed	PC	Hy
1970-1974	5	1	14	
1975	8	0	48	1
1976	6	0	55	1
1977	7	0	71	1
1978	8	1	64	1
1979	8	2	108	3
1980	8	4	134	1

Table 10. Population expansion of Prairie Chicken on the North East District.

Year	Active Display Grounds		Active Males	
	PC	Mixed	PC	Hy
1970-1974	1	1	10	2
1975	2	1	25	11
1976	4	0	26	9
1977	4	0	27	2
1978	1	1	37	2
1979	4	1	59	3
1980	5	0	62	4

Table 11. Change in number of active display grounds with male Prairie Chicken on three districts between 1975 and 1980.

West Central			South East			North East		
1975	1980		1975	1980		1975	1980	
PC	PC	Mix	PC	PC	Mix	PC	Mix	PC
5	5	4	3	3	15	1	26	1
6	6	7	3 sat	3 sat	27	39		26
7	8 W	8 E	15	16	29			34
8 W	9	13 W	16	17	45			39
9	11	30 S	17	19				40
11	12	42	19	25				
12	13 E		25	46 E				
13 W	21		27	46 W				
20	24							
21	28							
22	35							
24	37							
28	43							
	44							
	48							

Table 12. Male prairie grouse density of occupied habitat (mi²) and potential habitat (100.1 mi²) for spring and summer activity.

Year	Male Prairie Grouse Density			
	Occupied Habitat mi ²	acres	Occupied Habitat males/mi ²	Potential Habitat males/mi ²
1961	10.5	6,720	1.0	0.1
1962	14.0	8,960	0.8	0.1
1963	16.0	10,240	0.9	0.2
1971	28.0	17,920	1.7	0.5
1972	30.5	19,520	4.5	1.4
1973	35.0	22,400	4.2	1.5
1974	45.0	28,800	2.8	1.3
1975	51.0	32,640	4.2	2.2
1976	58.0	37,120	3.4	1.9
1977	60.0	38,400	4.1	2.5
1978	62.0	39,680	3.9	2.4
1979	73.0	46,720	7.0	5.1
1980	75.0	48,000	8.2	6.2

Occupied and potential habitat determined by dot grid on soil survey aerial photographs from Thompson and Joos 1975.

Table 13. Prairie Chicken (PC) nest site and outcome.

# of Nest Site	Date First Located	# of Eggs	Display Ground	Outcome	
				Success	Failure
1	16 Apr	0	1.0 mi.		Site Abandoned
2	7 May	0	1.0 mi.		Site Abandoned
3	28 May	2	1.0 mi.		Site Abandoned
4	30 May	12	.75 mi.	? Hatched	5 Unhatched
5	3 Jun	13	.88 mi.		Depredated, 1 Egg Remained
6	4 Jun	1	.38 mi.		Site Abandoned
7	6 Jun	16	.38 mi.	14 Hatched	2 Unknown
8	7 Jun	2	.63 mi.		Depredated by Skunk, 2 Eggs Remained
9	Jun	13	1.25 mi.	13 Hatched	
10	Jun	13	.88 mi.		Hen Killed by Haying Machine
11	26 Jun	11	.88 mi.	11 Hatched	

Table 14. Prairie Chicken (PC) nest site habitat description.

# of Nest Site	Habitat Type	Dominant Plants	Nest Site Size ft	Nest Site Area ft ²	Slope %	Aspect	Cover in dm 100% V.O.M.	Feet to Short Cover of ≤ 1.0 dm 100% V.O.M.
1	Midland	switchgrass	2 X 2.5	3.93	1%	SE	-----	100
2	Midland	switchgrass	1 X 1.5	1.18	5%	W		5
3	Cropland	alfalfa	-----	-----	-----	-----	-----	-----
4	Midland	switchgrass	2 X 2	3.14	0%		4.0	150
5	Midland	switchgrass	1.5 X 2	2.36	5%	SE	2.3	8
6	Midland	big blue, switchgrass	1 X 1.5	1.18	5%	W	1.5	3
7	Midland	switchgrass, sweet clover	1.5 X 1.5	1.77	0%		2.9	75
8	Midland	big blue, switchgrass	2 X 3	4.71	5%	W	1.4	5
9	Midland	switchgrass	-----	-----	2%	E	-----	12
10	Cropland	alfalfa	-----	-----	-----	-----	-----	-----
11	Midland	switchgrass	2 X 2	3.14	0%		2.7	75



Prairie Chicken, Female on a Nest. Photo by Lee Manske



Prairie Chicken, Nest with Eggs. Photo by Lee Manske



Prairie Chicken Brood. Photo by Lee Manske

Table 15. Criteria used to help estimate age of Prairie Chicken Chicks in broods observed in the field.

Age in Weeks	Age in Days	Body Size in Relation to Adult	General Plumage Characteristics
1	7		Downy appearance, cannot fly
1.5	10		Wing feathers appear, can fly 50 ft.
3	21	<1/3	Juvenal breast feathers appear, can fly 100 yds.
4	28	1/3	Breast fully feathered
5	35	<1/2	Juvenal plumage nearly complete
6	42	1/2	Juvenal plumage nearly complete
7-8	49-56	>1/2	Juvenal plumage complete
9	63	<3/4	Immature plumage appearing
10	70	3/4	Immature plumage developing
11-12	77-84	>3/4	Bar markings on breast
13	91	<Full	Not easily distinguished from adult
14	98	Full	Immature plumage nearly complete Weight less than adult

Table 16. Number of chicks in prairie chicken broods with complete counts and estimated age in days for biweekly periods.

Biweekly Period	Brood Size n=43	Age in Days n=49
15-30 Jun	9.8	11
1-15 Jul	10.0	26
16-31 Jul	8.3	40
1-15 Aug	7.2	50
16-31 Aug	7.0	80
1-15 Sep	6.8	78
Mean	8.0 ± 3.9	

Table 17. Prairie Chicken (PC) brood and habitat description.

Brood Number	Date Located	# of Chicks	Estimated age in days	Habitat Type	Dominant Plants
1	20 Jun	11	7	Upland	spiraea
2	24 Jun	2	10-14	Midland	switchgrass
3	25 Jun	16	2-3	Upland	buckbrush
4	27 Jun	11	1	Midland	switchgrass
5	29 Jun	13	25	Midland	spiraea
6	29 Jun	6	10-14	Upland	lead plant
7	8 Jul	10	21	Upland	lead plant
8	11 Jul	1	25	Upland	lead plant-K. bluegrass
9	13 Jul	10	14	Cropland	alfalfa
10	13 Jul	10	35	Cropland	alfalfa (mowed)
11	15 Jul	2+	35	Upland	blue grama-lead plant
12	18 Jul	?		Midland	prairie cordgrass
13	18 Jul	?		Upland	lead plant
14	21 Jul	10	21	Midland	switchgrass
15	22 Jul	9	70	Midland	switchgrass
16	23 Jul	?	10	Cropland	alfalfa
17	24 Jul	6	42	Lowland	sedge
18	24 Jul	5	14	Lowland	willow
19	25 Jul	?		Midland	switchgrass
20	25 Jul	?		Lowland	sedge
21	25 Jul	9	70	Lowland	sedge
22	26 Jul	9	70	Lowland	sedge
23	28 Jul	10	50	Upland	spiraea
24	29 Jul	7	?	Lowland	switchgrass-sedge
25	30 Jul	1	35	Lowland	willow
26	30 Jul	11		Upland	spiraea-lead plant
27	30 Jul	8	14	Midland	switchgrass-sweet clover
28	31 Jul	9	42	Midland	sweet clover-K. bluegrass
29	31 Jul	1	63	Midland	switchgrass
30	31 Jul	7	18	Upland	lead plant

Table 17. Prairie Chicken (PC) brood and habitat description.

Brood Number	Date Located	# of Chicks	Estimated age in days	Habitat Type	Dominant Plants
31	2 Aug	2	50	Lowland	sedge
32	3 Aug	1	42	Midland	willow
33	3 Aug	3	42	Upland	lead plant
34	3 Aug	4	42	Upland	lead plant
35	5 Aug	14	42	Midland	willow
36	7 Aug	7	35	Midland	switchgrass-red top
37	10 Aug	4	70	Lowland	sedge
38	11 Aug	7	45	Cropland	alfalfa
39	13 Aug	4	63	Midland	switchgrass-sweet clover
40	14 Aug	11	70	Upland	lead plant
41	14 Aug	11	45	Lowland	sedge-red top
42	17 Aug	12	80	Midland	big bluestem-buckbrush
43	22 Aug	14	80	Midland	switchgrass
44	28 Aug	2	70	Midland	switchgrass
45	28 Aug	1 Hy	63	Midland	lead plant
46	29 Aug	7	90	Upland	lead plant
47	29 Aug	2	?	Midland	switchgrass-little bluestem
48	30 Aug	13	84	Midland	switchgrass (burned spring)
49	31 Aug	11	90	Upland	lead plant
50	31 Aug	1	80	Midland	little bluestem
51	1 Sep	1	70	Upland	lead plant
52	1 Sep	11	70	Midland	willow
53	1 Sep	8	70	Midland	willow
54	4 Sep	7	84	Midland	bromegrass
55	9 Sep	1	95	Midland	switchgrass

Table 18. Prairie grouse brood habitat quality of six representative sites.

Brood habitat Site Number	Habitat Type	Height-Density in decimeters		Dominant Plants
		100% VOM	0% VOM	
1	Upland	1.6	3.6	Lead plant-rose
2	Midland	1.9	6.4	Switchgrass
3	Midland	2.3	6.0	switchgrass-northern reed
4	Midland	2.4	6.6	Switchgrass-willow
5	Lowland	1.8	5.0	sedge-switchgrass-northern reed
6	Lowland	1.9	6.3	Sedge-willow

Table 19. Percent of readings at half decimeters of height-density pole 100% VOM at six representative brood habitat sites.

Half Decimeter	Brood Habitat Sites					
	#1 Upland	#2 Midland	#3 Midland	#4 Midland	#5 Lowland	#6 Lowland
0.0	0	0	0	0	0	0
0.5	5	0	0	0	0	0
1.0	30	3	0	5	15	5
1.5	25	30	9	12	27	30
2.0	25	52	44	25	42	55
2.5	12	10	31	30	12	10
3.0	3	5	16	20	4	
3.5				5		
4.0				3		
% at 1.5 dm or above	65	97	100	95	85	95

1 dm=3.94 in

Table 20. Percentage of prairie grouse night roost sites located in habitat types.

Habitat Type		Spring	Summer	Fall	Winter
Upland	blue grama	5.3	0.0	0.0	1.8
Midland	big bluestem	1.3	0.0	14.8	1.8
Midland	switchgrass	57.9	77.6	72.2	24.6
Lowland	woolly sedge	35.5	22.4	13.0	0.0
Cropland	aftermath	0.0	0.0	0.0	33.3
Shelterbelt	trees	0.0	0.0	0.0	38.6

Table 21. Percentage of prairie grouse day roost sites located in habitat types.

Habitat Type		Spring	Summer	Fall	Winter
Upland	blue grama	10.0	83.3	0.0	0.0
Midland	big bluestem	0.0	0.0	0.0	0.0
Midland	switchgrass	90.0	0.0	100.0	0.0
Lowland	woolly sedge	0.0	16.7	0.0	0.0
Cropland	aftermath	0.0	0.0	0.0	0.0
Shelterbelt	trees	0.0	0.0	0.0	0.0

Table 22. Surface area of Habitat Types and Habitat Complexes.

Habitat Complex Habitat Type	Hectare	Acre	mi ²	Percentage
Hummocky Sandhills	26,505.4	65,494		50.16
Upland Grassland	13,917.2	34,389	53.7	26.34
Midland Grassland	6,701.0	16,558	25.9	12.68
Lowland Grassland	5,154.7	12,737	19.9	9.76
Cropland	732.5	1,810	2.8	1.39
Deltaic Plain	15,686.6	38,761		29.69
Midland Grassland	5,858.4	14,476	22.6	11.09
Lowland Grassland	2,180.1	5,387	8.4	4.13
Cropland	7,648.0	18,898	29.5	14.47
Choppy Sandhills	7,758.1	19,170		14.68
Upland Woodland	4,967.3	12,269	19.2	9.40
Open Grassland	2,792.8	6,901	10.8	5.29
River Terrace	2,887.5	7,135		5.46
Riparian Forest	2,310.8	5,710	8.9	4.37
Cropland	576.7	1,425	2.2	1.09

Data from Manske 1980.

Table 23. Habitat Use Index (% of bird locations/% of study area) for Prairie Chicken during annual phenological activities.

Habitat Complex Habitat Type	% of Sandhills	Spring 1 Apr-15 Jun	Summer 16 Jun-31 Aug	Fall 1 Sep-15 Nov	Winter 16 Nov-31 Mar
Hummocky Sandhills	50.16	1.89	1.78	0.73	0.36
Upland Grasslands	26.34	1.64	1.18	0.55	0.14
Midland Grasslands	12.68	3.38	3.34	0.42	0.34
Lowland Grasslands	9.76	0.76	1.27	0.17	0.01
Cropland	1.36	0.97	2.65	11.12	6.11
Shelterbelts	0.03	0.00	0.00	0.00	55.81
Deltaic Plain	29.69	0.17	0.35	1.81	2.58
Upland Grasslands	0.01	5.49	0.00	1897.44	295.12
Midland Grasslands	11.09	0.40	0.34	0.94	0.99
Lowland Grasslands	4.13	0.14	0.49	5.90	0.89
Cropland	11.39	0.96	0.41	0.00	3.68
Shelterbelts	3.08	0.00	0.00	0.00	5.56
Choppy Sandhills	14.68	0.00	0.00	0.00	0.00
Upland Woodland	9.40	0.00	0.00	0.00	0.00
Open Grassland	5.29	0.00	0.00	0.00	0.00
River Terrace	5.46	0.00	0.00	0.00	0.00
Riparian Forest	4.37	0.00	0.00	0.00	0.00
Cropland	1.09	0.00	0.00	0.00	0.00
Transportation Routes					
Gravel Roads	0.52	0.00	0.00	7.89	1.04
(N)=		3642	638	780	3524

Table 24. Habitat Use Index (% of activity site/% of study area) for Prairie Chicken during annual phenological activities.

Habitat Complex Habitat Type	% of Sandhills	Display Ground Habitat	Nest Habitat	Brood Habitat
Hummocky Sandhills	50.16			
Upland Grasslands	26.34	1.90	0.00	1.27
Midland Grasslands	12.68	2.56	6.45	3.12
Lowland Grasslands	9.76	0.99	0.00	1.12
Cropland	1.36	0.00	0.00	1.14
Shelterbelts	0.03	0.00	0.00	0.00
Deltaic Plain	29.69			
Upland Grasslands	0.01	131.58	0.00	0.00
Midland Grasslands	11.09	0.40	0.00	0.46
Lowland Grasslands	4.13	0.32	0.00	0.62
Cropland	11.39	0.08	1.60	0.56
Shelterbelts	3.08	0.00	0.00	0.00
(N)=		228	11	54

Table 25. Habitat Use Index (% of activity sites/% of study area) for Prairie Grouse night and day roost sites with birds present.

Habitat Complex Habitat Type	% of Sandhills	Spring 1 Apr-15 Jun		Summer 16 Jun-31 Aug		Fall 1 Sep-15 Nov		Winter 16 Nov-31 Mar	
		Night	Day	Night	Day	Night	Day	Night	Day
Hummocky Sandhills									
Upland Grasslands	26.34	0.20	0.23	0.00	3.16	0.00	0.00	0.07	0.00
Midland Grasslands without switchgrass	12.68	0.10	0.00	0.00	0.00	1.17	0.00	0.14	0.00
Midland Grasslands with switchgrass	12.68	4.57	7.10	6.12	0.00	5.70	7.89	1.94	0.00
Lowland Grasslands	9.76	3.64	0.00	2.30	1.71	1.33	0.00	0.00	0.00
Deltaic Plain and Hummocky Sandhills									
Cropland	12.75	0.00	0.00	0.00	0.00	0.00	0.00	2.61	0.00
Shelterbelts	3.11	0.00	0.00	0.00	0.00	0.00	0.00	12.41	0.00
(N)=		76	10	49	6	54	23	57	0

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Activity and Habitat Use by Sharptailed Grouse of the Sandhills Region

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1192

Plains Sharptailed Grouse, *Tympanuchus phasianellus jamesi*, require various types of habitats to perform their annual seasonal activities. A six year study was conducted to determine the relationships among the major activities of courtship, nesting, and brood rearing performed during seasonal periods and the habitats selected for use from the available habitat types on the Sandhills region.

Procedure for Courtship Activity

Methods used for the spring census of sharptailed grouse followed the standard procedures described by Grange (1948) and Kirsch (1956). Listening routes were traversed during ½ hour before to 1 hour after sunrise to locate new display grounds. Stops were made at ¼, ½, to 1 mile intervals, motor was shut off, and observer moved away from vehicle to listen for prairie grouse display sounds for at least 2 or 3 minutes. Stops were plotted on a map with arrows drawn to show direction and estimated distance to grounds heard.

Each known display ground was visited 3 to 12 times per census period to count active male birds. The presence of all female birds observed was also recorded. Special precautions were made not to disturb the grounds by flushing the birds so other grounds in the vicinity could be censused without recounting any birds. A 7 power binoculars and a 25 power spotting scope were invaluable in census surveillance to record all active birds, and separation of male and female, and prairie chicken, sharptailed grouse, and hybrid.

Levels of male and female bird's activity on display grounds was evaluated. The relationship of daily and weekly display activity by male and female birds was determined as a percentage of the maximum daily and weekly male activity on the same grounds.

Prairie grouse spring courtship display grounds are anchored on the upland mixed grass prairie community with vegetation generally with short stature. It is not known if the Upland mixed grass prairie vegetation is acceptable as sites for

display grounds without grazing management and not known if the Midland tall grass prairie community is acceptable as suitable sites for display ground habitat without grazing and mowing management. To assess this unknown, the distance from the center of all dancing grounds with male sharptailed grouse was measured to the nearest livestock watering facility because the vegetation near livestock watering facilities tend to be grazed a little shorter than the typical level of vegetation on similar communities away from livestock watering facilities.

The location of dancing grounds appear to be associated with concealment cover adjacent or very near. Concealment cover quality of prairie wildlife habitat was evaluated by visual obstruction determined with the height-density pole developed by Robel et al. (1970a) and modified by Kirsch (1974). Twenty five pole sets with an interval of 12 paces were made in homogeneous vegetation along transects of 275 meters (900 ft) long. Four readings at a height of 1.0 meter and a distance of 4.0 meters (13 ft) were made at each pole set for the 0% and 100% visual obstruction measurements (VOM) to the nearest 0.5 decimeters (2 inches) at the four major compass directions. A mean 100% VOM at 1.5 dm (5.9 in) was considered to be good concealment cover (Manske 1981, Higgins and Barker 1982).

The annual cadastral description of the location of all active display grounds to the quarter, quarter, quarter section (ten acres) was recorded. Evaluation of the annual locations would indicate stability or movement of display grounds. The display ground locations cluster into three population districts. The addition of new display grounds would indicate occupied habitat expansion.

Procedure for Nesting Activity

Determination of successful nest site habitat required to know the location of representative nests. Two methods were used to locate nest sites. The cable-chain drag as described by Higgins, Kirsch, and Ball (1969) and Higgins et al. (1977) consisted of a 174 ft (53 m) length of 5/8 in (1.6 cm) steel cable with three loops of ¼ in (0.6 cm) steel chain attached

produce complimentary hormones that strongly influence the behavior of the birds. The auditory and visual signals of male sharptailed grouse in full courtship display further stimulates breeding behavior.

The male sharptailed grouse census indicates a low population during 1961 to 1970. During the first census efforts in 1961 no sharptailed grouse dancing grounds were located but several scattered birds were observed. A hybrid was active on one booming ground which indicates that a breeding male or female sharptailed grouse was active during a past mating season. During 1963, the first dancing ground was located audially but not counted. During 1970, a second dancing ground was located and counted with 11 male sharptailed grouse. This ground was located and counted in 1961 and 1962 with one male prairie chicken each year.

During 1961 to 1967, all 56 allotments were grazed 6 months seasonlong from mid May to mid November, providing little adequate concealment habitat for the sharptailed grouse. During 1968 to 1970, a few allotments were cross fenced and some multiple pastures were grazed one time per year with one of the pastures deferred until late season. In 1971, 18 pastures from 15 allotments, about 10% of the land were grazed two times per year.

The spring prairie grouse census reflects the grazing management practice of the previous season or two. The spring census of 1971 found three dancing grounds with 25 male sharptailed grouse, and 1 booming ground had 4 male sharptailed grouse; these 4 display grounds had 29 male sharptailed grouse. The spring census of 1972 found that 3 dancing grounds had 32 males, 2 mixed grounds had 19 males, and 2 booming grounds had 5 males; these 7 display grounds had a huge increase of 56 male sharptailed grouse. The spring census of 1973 found that 5 dancing grounds had 40 males, 1 mixed ground had 6 males, and 3 booming grounds had 6 males; these 9 display grounds had 52 male sharptailed grouse (tables 1, 2, 3, and 4).

In 1974, 14 allotments, 26% of the land, had all pastures grazed 2 times per year. The number of pastures with two grazing periods per year increased each grazing season until the peak in 1978 when 54% of the land was managed with two grazing periods per year.

The spring census of 1975, found that 5 dancing grounds had 46 males, 1 mixed ground had 4 males, and 2 booming grounds had 3 males; these 8

display grounds had 53 male sharptailed grouse. The spring census of 1977, found that 6 dancing grounds had 35 males, 3 mixed grounds had 15 males, and 1 booming ground had 1 male; these 10 display grounds had 51 male sharptailed grouse. There had not been an increase in the number of male sharptailed grouse active on the display grounds censused from 1972 to 1978 (tables 1, 2, 3, and 4).

The spring census of 1979, found that 12 dancing grounds had 104 males, 10 mixed grounds had 45 males, and 3 booming grounds had 7 males; these 25 display grounds had a huge increase to 156 male sharptailed grouse. The spring census of 1980, found that 12 dancing grounds had 110 males, 8 mixed grounds had 65 males, and 7 booming grounds had 15 males; these 27 display grounds had an increase to 190 male sharptailed grouse (tables 1, 2, 3, and 4).

The display ground activity levels are assumed to be similar in male and female sharptailed grouse. The male birds start courtship activity on dancing grounds around 15 to 20 March. The female birds are visible on dancing grounds about a week later. Male birds arrive 1 hour to ½ hour before sunrise and most vocal activity occurs from dawn until ½ hour to 1 hour after sunrise, display activity slows down but continues until 8 or 9 o'clock depending on weather conditions or presence of female birds. Intense levels of courtship display occurs from 7 to 28 April with peak activity from 14 to 20 April. Activity continues after 28 April at low intensity but has renewed activity during late May to mid June when renesting females return to the dancing grounds (figure 1).

Male hybrid activity on display grounds was extremely erratic, they come and go, even during peak display periods (table 5). Very few female hybrids were identified showing interest on display grounds and only during peak display periods.

The male sharptailed grouse breakup into small groups after mid June but remain in the vicinity of the display ground all summer.

The distance from the center of the display ground to the nearest livestock watering facility was measured for 87 dancing grounds with active male sharptailed grouse. Most, 48 grounds (55%), were located near a livestock water facility with vegetation grazed shorter than the typical level and had a mean distance of 569 ft (173 m). The other display grounds, 39 grounds (45%), were greater than 1500 ft (457 m) from a livestock watering facility. 23

grounds (26%) were restricted to the upland mixed grass prairie community with short stature vegetation. 11 grounds (12.6%) had been mowed during the previous year. Only 5 grounds (5.7%) had male sharptailed grouse displaying on the midland tall grass prairie community that had not been mowed the previous year and was greater than 1500 ft (457 m) from livestock water. No sharptailed grouse males displayed on unmowed lowland sedge meadow community. The vegetation height stature had been reduced by grazing or mowing management on the sites of 59 grounds (68%) selected by male sharptailed grouse and the sites selected for only 28 grounds (32%) had vegetation at typical level.

The quality of concealment cover adjacent or very near spring display grounds was determined for 87 dancing grounds by the height-density pole method. The concealment cover was very good with mean 100% VOM at greater than 1.5 dm (5.9 in) on 70 grounds (80.5%). The concealment cover was good with mean 100% VOM near 1.5 dm (5.9 in) on 11 grounds (12.6%). The concealment cover was poor with mean 100% VOM at less than 1.5 dm (5.9 in) on 6 grounds (6.9%). Most dancing grounds, 81 grounds (93.1%), had good or very good concealment cover adjacent or very near with mean 100% VOM at or greater than 1.5 dm (5.9 in).

Prairie grouse census started in 1961 that located 6 display grounds. The first dancing ground was located in 1963. The second dancing ground was located in 1970 which had changed from being a booming ground in 1961 and 1962.

By 1980 (year 20), the location of 13 dancing grounds was known (table 6). Four dancing grounds had been known for only one or two years and had not yet moved. Nine (69.2%) of the dancing grounds had changed locations. These dancing grounds had been active for an average of 5.6 years, moved an average of 3.7 times, at a rate of movement during 78.8% of their active years. The mean distance moved was 0.57 miles (0.92 km). The mobility of each display ground was limited to a territory or movement zone of varying size with a mean of 0.68 X 0.39 miles (1.1 X 0.63 km) with 195 acres (79 ha) (table 6).

The sharptailed grouse population congregate into three major districts (figure 2). During the period of 1971 to 1980, the number of male sharptailed grouse, the number of dancing grounds, and mixed display grounds, and the quantity of occupied habitat greatly increased on each of the population districts.

The West Central District was located west of McLeod (tables 7 and 10). In 1975, it had 2 dancing grounds with 14 male sharptailed grouse. During the consecutive five years, 1 dancing ground remained active, 1 dancing grounds changed to a mixed ground, 5 new dancing grounds were added, and 5 new mixed grounds were added. During 1980, there were 6 dancing grounds and 6 mixed grounds with 111 male sharptailed grouse and 6 hybrids (table 7 and figure 2).

The South East District was located south and east of McLeod (tables 8 and 10). In 1975, it had 1 dancing ground with 15 male sharptailed grouse and 1 hybrid. During the consecutive five years, the 1 dancing ground remained active, 1 new dancing grounds was added, and 4 new mixed grounds were added. During 1980, there were 2 dancing grounds and 4 mixed grounds with 37 male sharptailed grouse (table 8 and figure 2).

The North East District was located north and east of McLeod (tables 9 and 10). In 1975, it had 2 dancing grounds and 1 mixed ground with 24 male sharptailed grouse and 3 hybrids. During the consecutive five years, 2 dancing grounds remained active, 1 mixed ground was active during 4 of the 6 years, and 1 new dancing ground was added. During 1980, there were 3 dancing grounds with 36 male sharptailed grouse and 1 hybrid (table 9 and figure 2).

Unfortunately, in 1979, the grazing management was drastically changed to multiple pastures grazed one time and one of the pastures deferred until late season. The number of pastures grazed two times per year were rapidly reduced to zero shortly after 1979. This major change in grazing management practices terminated the 10 year (1971 to 1980) period with encouraging increases in sharptailed grouse population. After these changes in grazing management, the sharptailed grouse has had wide irregular fluctuations with a greatly decreased number.

Results for Nesting Activity

Female sharptailed grouse visit the dancing ground several times before she submits to copulate with the male of her choosing, which is not always the dominant male. The hen had previously selected a nest site with good visual obstruction cover. After mating, she finishes building the ground nest. The first egg is laid in about 3 days (1 to 5 days), followed by one egg per day, until a full clutch with a mean of 13 eggs (12 to 15 eggs) (table 11). Incubation starts after all the eggs are laid and usually takes 25 days

(23 to 27 days). The hen leaves the nest for brief periods to feed but spends most of the time on the nest, the male does not help.

Three nests were located by the cable-chain drag, 1 nest was located during a prescribed burn, 4 nests were located by the dogs, and a dog was used to relocate 2 nests that the marker flag had been removed by curious deer.

The mean distance of the nest sites to the nearest display grounds was 0.75 miles (table 11). However, the hen may not have mated on the nearest display ground. All eight of the nest sites were located in native vegetation of the midland tall grass prairie community. Switchgrass was the dominant species at all of the nest sites except, one nest was located near a white spiraea shrub with Kentucky bluegrass the dominant grass and switchgrass was a subdominant. The immediate nest sites were characteristically completely covered by vegetation. The sides and top were very dense residual and growing vegetation. The mean 100% VOM at nest center was 2.58 dm (10.2 in). Some nest sites had a definable hole in the vegetation for the hen to pass in or out. Most of the nest sites had an elliptical shape with the mean dimensions of 1.9 X 2.3 ft and an area of 3.11 ft². All of the nest sites were located on relatively level topography, with slopes of 1% to 5%, and the aspect was mostly north or south (table 12).

The surrounding nest cover had a mean 100% VOM of 2.4 dm (9.5 in). The distance to short vegetation of less than 1 dm (3.9 in) was categorized into narrow (<10 ft) (<3.0 m), medium (to 50 ft) (to 15.2 m), and wide (>50 ft) (>15.2 m) cover (table 12). Two nest sites were in narrow cover with a mean of 4.5 ft (1.4 m) to short vegetation. One of these nests were lost to high soil moisture and the other nest was believed to have been successful because it was in some of the best cover measured with a 100% VOM at 3.1 dm (12.2 in). Four nest sites were in medium cover with a mean of 20.8 ft (6.3 in) to short vegetation. Two of the nests had been located during the early stages of egg laying and were abandoned, 1 nest was lost during a prescribed burn, the hen escaped, and on the fourth nest, 9 of 10 eggs hatched. Two nest sites were in wide cover with a mean of 150 ft (45.8 in) to short vegetation. One of the nests had partial success with 12 of the 14 eggs hatched, and the other nest had 13 eggs hatch (tables 11 and 12).

Results for Brooding Activity

Sharptailed grouse chicks have an “egg tooth” which is a hard white growth on the end of their bill to help them break the eggshell from inside. It disappears soon after hatching. The chicks are precocial, they are covered with down, the eyes are open, they can walk and feed themselves as soon as they are dry. Most of the first day is spent on or near the nest site. The chicks eat a high protein diet of mostly insects and grow very fast. They are capable of short flights at 7 to 10 days old. At 90 days old, the young cannot easily be distinguished from adult plumage, except the chicks are still lighter weight.

The estimated age of the chicks was based on the relative body size in relation to an adult bird and the stage of plumage development (table 13). At the time, the research to identify the stages for aging young prairie grouse were for birds in the hand, not for field observations.

The sharptailed grouse brood search was conducted for 6 years from mid June to mid September. The trained bird dogs located 13 broods and 15 broods were located by vehicle transects. Two broods of hybrid chicks with sharptailed grouse hens were located (table 15).

The sharptailed grouse brood size tended to decrease with time. The mean sharptailed grouse completed clutch size was 13 ± 1.79 eggs. About 50% of the nests hatch some eggs. The mean number of eggs that hatched from successful nests was 12 ± 1.63 eggs. The brood size in late June was 9.7 chicks, by late July the brood size was 9.2 chicks and by late August the brood size had decreased to 7.0 chicks (table 14). The higher percent of losses appears to occur early after hatch. From a full clutch of eggs in a nest to late August, the hens had been able to save about 50% of their chicks, which seems to be a remarkable accomplishment. During a biweekly period, the age of young birds had a wide spread in age of about 26 days from youngest to oldest.

Sharptailed grouse broods were located in a wide variety of habitats with 54% in shrubs and 46% in grass (table 15). Thirteen (46%) broods were located in the upland mixed grass prairie communities with 85% in shrubs of lead plant, buckbrush, green sage, oak saplings, rose, and willow, and 15% in blue grama. Six (21%) broods were located in the midland tall grass prairie communities with 67% in shrubs of spiraea, lead plant, buckbrush, and wild licorice, and

33% in grass of switchgrass and Kentucky bluegrass. Nine (32%) broods were located in the lowland sedge meadow with sedge and grasses of woolly sedge, Kentucky bluegrass, and northern reed.

Sharptailed grouse broods were very mobile and travel over a large area and use several habitat types. Areas of shorter vegetation that had been mowed or grazed were used as feeding areas. The adjacent areas of dense residual and growing vegetation were used for escape cover and loafing. Broods usually used areas that had a high amount of shrubs and forbs. These areas usually provided good canopy cover and relatively open understories.

The height-density pole was used to evaluate the quality of six prairie grouse brood habitat sites (tables 16 and 17). The upland shrub site had a mean 100% VOM of 1.6 dm (6.3 in) with 65% of the reading at or above 1.5 dm. The two midland grass sites had mean 100% VOM of 1.9 dm (7.5 in) and 2.3 dm (9.1 in) with 97% and 100% of the readings at or above 1.5 dm. The midland grass-shrub site had a mean 100% VOM of 2.4 dm (9.5 in) with 95% of the readings at or above 1.5 dm. The lowland sedge-grass site had a mean 100% VOM of 1.8 dm (7.1 in) with 85% of the readings at or above 1.5 dm. The lowland sedge-shrub site had a mean 100% VOM of 1.9 dm (7.5 in) with 95% of the readings at or above 1.5 dm (tables 16 and 17). Prairie grouse hens selected very good concealment cover for their broods.

Results for Sharptailed Grouse Habitat Usage

The Sandhills region was comprised of eleven habitat types grouped into four habitat associations (table 18). The largest habitat association was the Hummocky Sandhills that consisted of 65,494 acres, and was 50.16% of the Sandhills region. It was comprised of the Upland mixed grass prairie habitat type that consisted of 34,389 acres, 26.34%, with blue grama, needle and thread, and upland sedge; the Midland tall grass prairie habitat type that consisted of 16,558 acres, 12.68% with little bluestem, big bluestem, and switchgrass; the Lowland sedge meadow habitat type that consisted of 12,737 acres, 9.76% with woolly sedge, northern reed, and baltic rush; and the Cropland habitat type that consisted of 1,810 acres, 1.39% with replacement vegetation.

The second habitat association was the Deltaic Plain that consisted of 38,761 acres, and was 29.69% of the Sandhills region. It was comprised of the Midland tall grass prairie habitat type that

consisted of 14,476 acres, 11.09%, with little bluestem, big bluestem, and Indian grass; the Lowland sedge meadow habitat type that consisted of 5,387 acres, 4.13% with woolly sedge, northern reed, and lowland sedge; and the Cropland habitat type that consisted of 18,898 acres, 14.47% with replacement vegetation.

The third habitat association was the Choppy Sandhills that consisted of 19,170 acres, and was 14.68% of the Sandhills region. It was comprised of the Upland Woodland grove and savanna habitat type that consisted of 12,269 acres, 9.40%, with bur oak, quaking aspen, and green ash; and the Open Grassland thin mixed grass prairie habitat type that consisted of 6,901 acres, 5.29% with blue grama, upland sedge, and sand dropseed.

The smallest habitat association was the River Terrace that consisted of 7,135 acres, and was 5.46% of the Sandhills region. It was comprised of the Riparian Forest habitat type that consisted of 5,710 acres, 4.37% with basswood, American elm, green ash, and box elder; and the Cropland habitat type that consisted of 1,425 acres, 1.09% with replacement vegetation.

Transportation Routes have been constructed across the Sandhills region. Gravel Roads have a total length of 112 miles with 679 acres of right of way, 0.52%; Railroads have a total of 17.5 miles of track with 106 acres of right of way, 0.08%; and Asphalt Roads have a total length of 13 miles with 79 acres of right of way, 0.06%.

Habitat usage by sharptailed grouse during four seasonal periods was determined by the habitat use index (% of bird locations/% of study area). The spring activity period occurred over 2.5 months from 1 April to 15 June with 958 observations of sharptailed grouse performing seasonal activities. The habitat use index for the Hummocky Sandhills was high at 1.98, for the Deltaic Plain was zero; for the Choppy Sandhills was very low at 0.06, and for the River Terrace was zero. The habitat use index for the Upland mixed grass prairie was at 2.48, for the Midland tall grass prairie was at 2.33, for the Lowland sedge meadow was at 0.34, and for the Cropland area was at 0.61 of the Hummocky Sandhills. The Upland Woodland was at 0.09 of the Choppy Sandhills. The habitat types of the Deltaic Plain and River Terrace had habitat use index at zero (table 19).

The summer activity period occurred over 2.5 months from 16 June to 31 August with 350 observations of sharptailed grouse performing seasonal activities. The habitat use index for the Hummocky Sandhills was high at 1.79, for the Deltaic Plain was at 0.08, for the Choppy Sandhills was at 0.53, and for the River Terrace was at zero. The habitat use index for the Upland mixed grass prairie was at 1.36, for the Midland tall grass prairie was at 2.57, for the Lowland sedge meadow was at 1.96, and for the cropland was at 1.89 of the Hummocky Sandhills, which were used for concealment cover and protection from the hot sun by the males and for nest and brood cover by the hens. The Lowland sedge meadow was at 0.48, and the Midland tall grass prairie was at 0.03 for the Deltaic Plain which were used for concealment, protection from the hot sun, and brood cover and feeding areas (table 19).

The Fall activity period occurred over 2.5 months from 1 September to 15 November with 210 observations of sharptailed grouse performing seasonal activities. The habitat use index for the Hummocky Sandhills was at 1.62, for the Deltaic Plain was at 0.53, for the Choppy Sandhills was at 0.06, and for the River Terrace was at zero. The Fall period had several changes with a shift from grassland habitats to cropland habitats, the hens leave her brood which brake up and disperse, and adult and juvenile birds gather at fall display grounds forming small winter flocks. The greatest habitat use index for the Upland mixed grass prairie was at 190.48, the Lowland sedge meadow was at 3.11, and the Midland tall grass prairie was at 0.09 of the Deltaic Plain primarily because of the large quantity of buckbrush on the Upland which was used by males and broods for concealment cover, shade, and the ripe berries for food. The Midland tall grass prairie was at 4.62, the Upland mixed grass prairie was at 0.76, the Cropland was at 0.70, and the Lowland sedge meadow was at 0.20 of the Hummocky Sandhills, and the Open Grassland was at 0.18 of the Choppy Sandhills which were used for shade and concealment cover (table 19).

The gravel roads had a high use index during the fall at 3.66 which were used for grit, for spilled grain moved from field to storage, and for dust baths. Rose hip seeds were used for grit during every month of the year.

The Winter activity period occurred over a long 4.5 months from 16 November to 31 March with 1,248 observations of sharptailed grouse performing seasonal activities. The habitat use index for the

Deltaic Plain was high at 2.16, for the Choppy Sandhills was at 0.39, for the Hummocky Sandhills was at 0.34, and for the River Terrace was at zero. The shift from grassland habitat to cropland habitat and adjacent tree shelterbelts had been completed. The high index for cropland area was at 5.07 and for shelterbelts was at 32.05 for the Hummocky Sandhills and for cropland was at 4.28 and shelterbelts was at 3.51 for the Deltaic Plain which indicates the importance of agricultural food sources during the winter. The Open Grassland was at 1.01, and the Upland Woodland was at 0.03, of the Choppy Sandhills, the Midland tall grass prairie was at 0.42, of the Deltaic Plain, and the Upland mixed grass prairie was at 0.31, the Midland tall grass prairie was at 0.03, and the Lowland sedge meadow was at 0.08 of the Hummocky Sandhills which were used for loafing areas between the morning and evening feeding periods (table 19).

Sharptailed grouse used the grassland habitats of the Hummocky Sandhills during the spring, summer, and fall and moved to the cropland habitat and adjacent planted tree shelterbelts of the Hummocky Sandhills and Deltaic Plain during winter. Sharptailed grouse used the grassland habitat and short shrub and sapling tree zone at the edge of mature tree groves and savanna of the Choppy Sandhills. They did not use the mature tree areas of the Choppy Sandhills and River Terrace.

Habitat usage by sharptailed grouse during three critical activities of courtship, nesting, and brood rearing were determined by the habitat use index (% of bird locations/% of study area). The critical courtship and mating activity is performed on communal display grounds (dancing grounds) had 88 observations. Each display ground is anchored on the Upland mixed grass prairie with an habitat use index of 2.76 and for the Midland tall grass prairie was at 2.15 of the Hummocky Sandhills. The Upland mixed grass prairie was grazed. The Midland tall grass prairie was used by males as courtship territories if mowed the previous year and used as concealment cover by males and females if not mowed the previous year. No sharptailed grouse used habitats of the Deltaic Plain for display grounds (table 20).

The critical nesting activity was performed solely by the females with no help from the males had 8 observations. Each nest site is placed in very good concealment cover with high visual obstruction. The habitat use index value was high at 7.88 for the switchgrass portion of the Midland tall grass prairie of the Hummocky Sandhills. The switchgrass

community was the only habitat found to be used by sharptailed grouse for nesting (table 20).

The critical brood rearing activity was performed solely by the females with no help from the males had 28 observations. All broods that were accompanied by a hen used a wide variety of habitats for concealment cover and feeding. Usually the brooding habitat had an abundance of short shrubs and forbs that provided good canopy cover and open understory. The habitat use index for the Midland tall grass prairie was at 2.34, for the Lowland sedge meadow was at 1.58, and for the Upland mixed grass prairie was at 1.56 of the Hummocky Sandhills; for the Lowland sedge meadow was at 0.69 of the Deltaic Plain; and for the Upland Woodland was at 1.17 of the Choppy Sandhills. Mature woodland areas were not used by sharptailed grouse (table 20).

Discussion

Long term survival of sharptailed grouse in the Sandhills region depends on the availability of short stature habitat for courtship activities, good concealment cover for nesting, brooding, roosting, and escaping activities, and agricultural commodities for winter food. The quality of the grassland habitats is greatly affected by the type of grazing management implemented.

The 6 month seasonlong treatment resulted in a mean 100% VOM of the switchgrass zone at 1.3 dm (5.1 in) with 43% readings at or above 1.5 dm during spring, 13% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly increased with Kentucky bluegrass, and decreased with cool and warm season native grasses.

The deferred grazing treatment resulted in a mean 100% VOM of the switchgrass zone at 1.6 dm (6.3 in) with 62% readings at or above 1.5 dm during spring, 20% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly increased with Kentucky bluegrass, and decreased with switchgrass, warm and cool season native grasses, and upland sedges.

The two pasture switchback strategy resulted in a mean 100% VOM of the switchgrass zone at 1.7 dm (6.7 in) with 63% readings at or above 1.5 dm during spring, 30% of the herbage biomass samples from the Upland and Midland communities were

greater on the grazed area than on the ungrazed area, and the plant species composition significantly decreased with switchgrass, warm and cool season native grasses, and upland sedges.

The allotments with multiple pastures grazed two times per year resulted in a mean 100% VOM of the switchgrass zone at 2.0 dm (7.9 in) with 78% readings at or above 1.5 dm during spring, 32% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly increased with switchgrass, lowland sedge, warm and cool season native grasses, upland sedges, and total basal cover.

During the 28 year period that all 56 allotments were grazed with 8 month or 6 month seasonlong, the male sharptailed grouse population remained very low with probably no more than 5 or 6 males. During the 3 year period that 39% of the land was managed with multiple pastures grazed one time per year with one pasture deferred to late season, the census documented 11 male sharptailed grouse on the spring of the third year. During the next 3 years, 10% of the land was grazed two times per year, by the spring of the third year, the number of male sharptailed grouse increased to 52. During the next 5 years the quantity of land managed with grazing two times increased from 26% to 54% of the land and the male sharptailed grouse census increased to 156 with the increase continuing for one additional year, with a peak sharptailed grouse census at 190 males. Then the grazing management was changed back to multiple pastures grazed one time per year with one pasture deferred to late season and the pastures grazed two times per year were decreased to zero causing the sharptailed grouse population to have wide irregular fluctuations with a declining trend. This drastic change in grazing management effectively terminated the expansion in the sharptailed grouse population.

During this 10 year improvement period, the sharptailed grouse population increased from 29 to 190 males, the quantity of land managed with two grazing periods per year increased from 10% to 54%, which greatly increased the quantity and quality of the available concealment cover. The mean 100% VOM at 1.5 dm (5.9 in) was considered to be the minimum for good concealment cover.

During the period of increasing sharptailed grouse population, the concealment cover used for nesting activities had a mean 100% VOM at 2.4 dm (9.5 in). The concealment cover used for brooding

activities with upland shrubs had a 100% VOM at 1.6 dm (6.3 in), with midland grass had 100% VOM at 1.9 dm (7.5 in) and 2.3 dm (9.1 in), with midland shrubs had a 100% VOM at 2.4 dm (9.5 in), with lowland grass had a 100% VOM at 1.8 dm (7.1 in). The concealment cover used for night roosting activities had a mean 100% VOM at 1.6 dm (6.3 in) during spring and at 2.0 dm (7.9 in) during fall.

During the period with declining sharptailed grouse population, the available concealment cover would have decreasing quantity and quality that resulted after the drastic change to grazing management practices with multiple pastures grazed one time per year and one pastures deferred until late season. The type of grazing management implemented affects the quality of grassland habitat available to grassland wildlife.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.



Sharp-tailed Grouse, Male. Photo by Al Smith



Hybrid (Prairie Chicken X Sharp-tailed Grouse), Male. Photo by Ed Bry

Table 1. Active male spring census of Sharptailed Grouse on Dancing Grounds.

Dancing Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
4		11		9	8	8	11	10	4	2	3	3
4 S			7				1	1	3		6	10
10			13	19	5	4	4		11	14	11	15
14			5	4	5	12	15	7	15	7	10	8
18					17	16	15		1	2	6	9
20					5	2						14
31											16	16
32								2			3	2
33											24	12
38								3	1		10	10
41 N											7	6
41 S											2	
47											6	5
ST Males		11	25	32	40	42	46	23	35	25	104	110

Table 2. Active male spring census of Sharptailed Grouse on Mixed Display Grounds.

Mixed Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
7									7	1	2	4
13 E				17	6			3	4	7	1	1
13 W											8	8
15				2							2	2
26						1	4	1		3	1	
28								3	4	1	2	
30 N												17
30 S											2	3
42											12	16
44											6	
45										2	9	14
ST Males				19	6	1	4	7	15	14	45	65

Table 3. Active male spring census of Sharptailed Grouse on Booming Grounds.

Booming Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
1				1			1					1
8 E									1		1	2
11							2					
12			4	4	2							
17					3							
19					1							
21											1	1
22						1						
24						4						2
27											5	3
29												4
43												2
ST Males			4	5	6	5	3		1		7	15

Table 4. Total active male spring census of Sharptailed Grouse.

Type Display Ground	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
Dancing		11	25	32	40	42	46	23	35	25	104	110
Mixed				19	6	1	4	7	15	14	45	65
Booming			4	5	6	5	3		1		7	15
Total ST Males		11	29	56	52	48	53	30	51	39	156	190

Table 5. Active male spring census of Hybrid Grouse with Sharptailed Grouse on Display Grounds.

Display Ground Number	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
4					1	1						
4 S												1
10				1			1			1	1	
13 E				3	5				1			
13 W												2
14							2				2	1
18							1					
20						1						1
33											1	1
38												1
45										1	2	
Hybrid Males				4	6	2	4		1	2	6	7

Figure 1. Daily and weekly percentage of male (σ) and female (φ) sharp-tailed grouse (ST) present on the display grounds - 1975-1980.

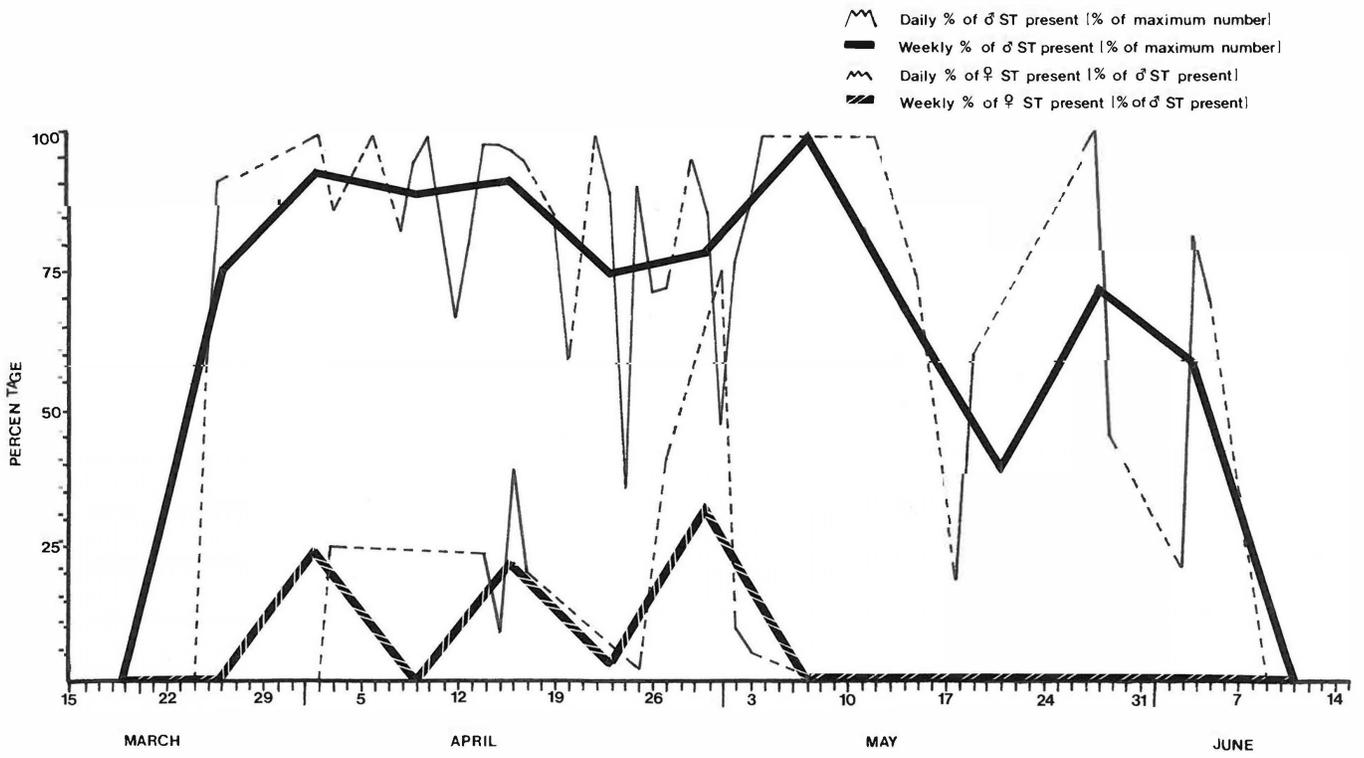


FIGURE 2. PRAIRIE GROUSE DISPLAY GROUNDS ON THE SHEYENNE NATIONAL GRASSLANDS-1980

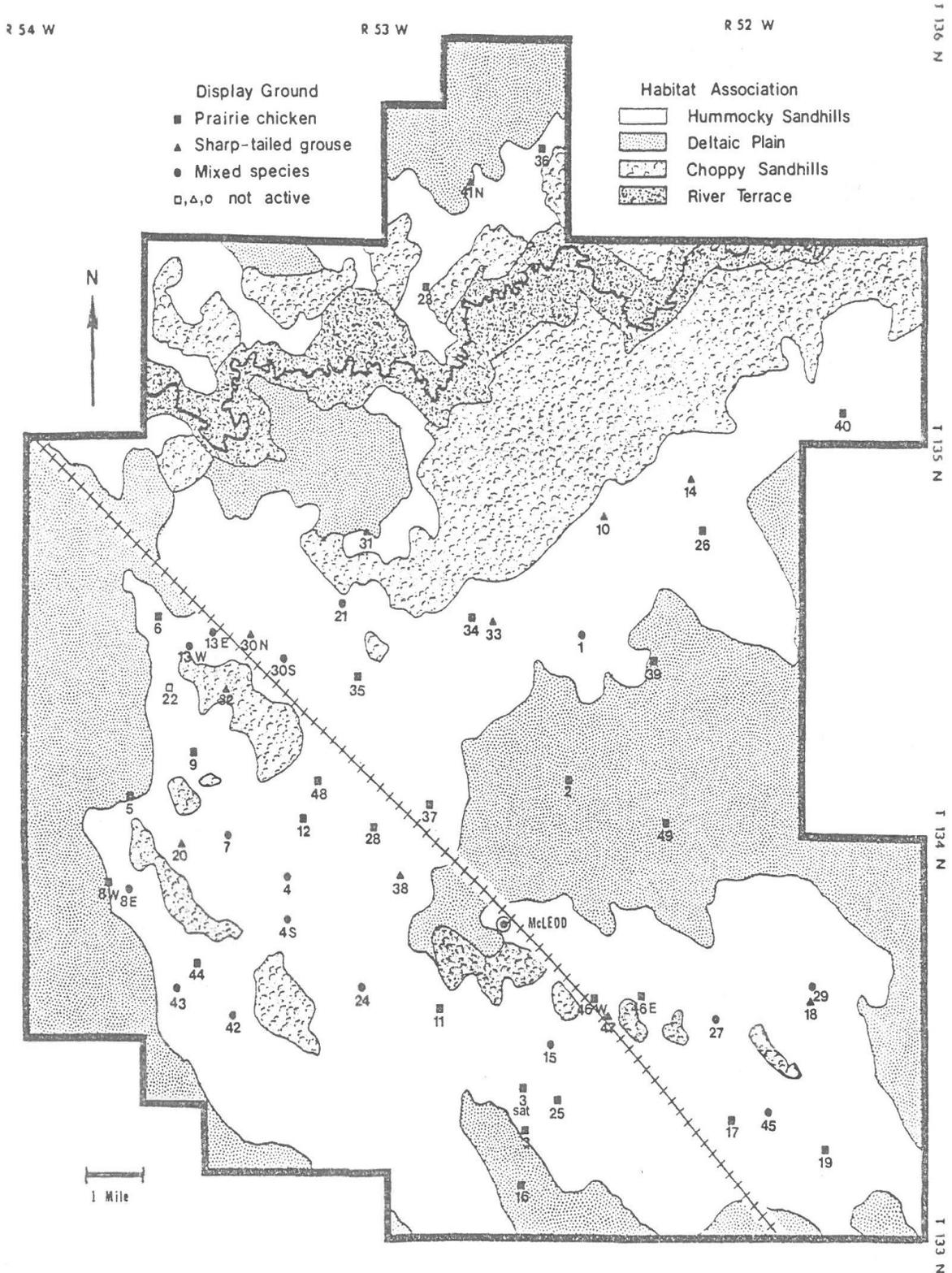


Table 6. Movement rate of spring Sharptailed Grouse Dancing Grounds

Dancing Ground Number	Years Censused #	Different Locations #	Movement Rate %	Distance Moved mi	Size Movement Zone mi X mi	Area Movement Zone acre
4	8	5	87.5	0.64	0.79 X 0.42	211
4 S	5	5	100.0	0.77	0.79 X 0.62	314
10	8	4	50.0	0.46	0.77 X 0.41	205
14	10	4	40.0	0.13	0.26 X 0.13	19
18	7	4	57.1	1.13	1.61 X 0.66	678
20	3	3	100.0	0.32	0.33 X 0.32	70
31	2	1	0.0	0.0		
32	3	3	100.0	0.76	0.77 X 0.16	77
33	2	1	0.0	0.0		
38	4	3	75.0	0.18	0.16 X 0.15	13
41 N	2	1	0.0	0.0		
41 S	1	1	0.0	0.0		
47	2	2	100.0	0.73	0.65 X 0.40	166
Mean N=9	5.6	3.7	78.8	0.57	0.68 X 0.39	195

Table 7. Population expansion of Sharptailed Grouse on the West Central District.

Year	Active Display Grounds		Active Males	
	ST	Mixed	ST	Hy
1970-1974	3	3	17	1
1975	2	0	14	
1976	5	1	22	
1977	3	3	24	1
1978	1	3	11	
1979	6	6	73	3
1980	6	6	111	6

Table 8. Population expansion of Sharptailed Grouse on the South East District.

Year	Active Display Grounds		Active Males	
	ST	Mixed	ST	Hy
1970-1974	1	1	7	
1975	1	0	15	1
1976	0	0	0	
1977	1	0	1	
1978	1	1	4	1
1979	3	2	28	
1980	2	4	37	

Table 9. Population expansion of Sharpsided Grouse on the North East District.

Year	Active Display Grounds		Active Males	
	ST	Mixed	ST	Hy
1970-1974	2	1	14	
1975	2	1	24	3
1976	1	0	8	
1977	2	0	26	
1978	2	1	24	1
1979	3	1	46	3
1980	3	0	36	1

Table 10. Change in number of active display grounds with male Sharptailed Grouse on three districts between 1975 and 1980.

West Central			South East			North East		
1975	1980		1975	1980		1975	1980	
ST	ST	Mix	ST	ST	Mix	ST	Mix	ST
4	4 S	4	18	18	15	10	26	10
4 S	20	7		47	27	14		14
	30 N	8 E			29			33
	31	13 W			45			
	32	30 S						
	38	42						

Table 11. Sharp-Tailed Grouse (ST) nest site and outcome.

# of Nest Site	Date First Located	# of Eggs	Display Ground	Outcome	
				Success	Failure
1	14 May	12	.50 mi.	? Hatched	
2	22 May	1	1.13 mi.		Site Abandoned
3	22 May	5+	1.13 mi.		Site Abandoned
4	25 May	14	.75 mi.	Hen Escaped	Site Burned
5	2 Jun	15	.75 mi.		High Moisture, 11 Eggs Remained
6	4 Jun	13	.88 mi.	13 Hatched	
7	6 Jun	14	.38 mi.	12 Hatched	2 Eggs Missing
8	19 Jun	10	.50 mi.	9 Hatched	

Table 12. Sharp-Tailed Grouse (ST) nest site habitat description.

# of Nest Site	Habitat Type	Dominant Plants	Nest Site Size ft	Nest Site Area ft ²	Slope %	Aspect	Cover in	Feet to Short
							100% V.O.M.	Cover of ≤ 1.0 dm 100% V.O.M.
1	Midland	switchgrass	2 X 3	4.71	5%	N	3.1	3
2	Midland	switchgrass	1.5 X 1.5	1.77	2%	S	1.6	20
3	Midland	switchgrass	1.5 X 1.5	1.77	2%	S	1.7	15
4	Midland	switchgrass	2 X 2	3.14	2%	NE	2.2	18
5	Midland	switchgrass	1 X 1.5	1.18	5%	N	2.5	6
6	Midland	switchgrass	3 X 3	7.07	1%	E	3.0	150
7	Midland	switchgrass	2 X 3	4.71	1%	S	2.7	150
8	Midland	spiraea, K. bluegrass	2 X 2.5	3.93	3%	N	2.2	30

Table 13. Criteria used to help estimate age of Sharptailed Grouse chicks in broods observed in the field.

Age in Weeks	Age in Days	Body Size in Relation to Adult	General Plumage Characteristics
1	7		Downy appearance, cannot fly
1.5	10		Wing feathers appear, can fly 50ft
3	21	<1/3	Juvenal breast feathers appear, can fly 100 yds
4	28	1/3	Breast fully feathered
5	35	<1/2	Juvenal plumage nearly complete
6	42	1/2	Juvenal plumage nearly complete
7-8	49-56	>1/2	Juvenal plumage complete
9	63	<3/4	Immature plumage appearing
10	70	3/4	Immature plumage appearing
11-12	77-84	>3/4	V-shaped markings on breast
13	91	<Full	Not easily distinguished from adult
14	98	Full	Immature plumage nearly complete Weight less than adult

Table 14. Number of chicks in Sharptailed Grouse broods with complete counts and estimated age in days for biweekly periods.

Biweekly Period	Brood Size n=19	Age in Days n=26
15-30 Jun	9.7	21
1-15 Jul	10.7	35
16-31 Jul	9.2	47
1-15 Aug	7.8	69
16-31 Aug	7.0	79
1-15 Sep	-	-
Mean	8.8 ± 3.3	

Table 15. Sharp-tailed Grouse (ST) brood and habitat description.

Brood Number	Date Located	# of Chicks	Estimated age in days	Habitat Type	Dominant Plants
1	25 Jun	21	21	Midland	spiraea
2	28 Jun	8	21	Upland	lead plant-green sage
3	6 Jul	11	35	Midland	switchgrass-K. bluegrass
4	7 Jul	11	25	Upland	lead plant-buckbrush
5	14 Jul	10	28	Upland	oak-cottonwood
6	15 Jul	15	50	Upland	oak
7	17 Jul	4	45	Lowland	sedge
8	18 Jul	3	?	Midland	switchgrass
9	20 Jul	13	60	Upland	buckbrush-green sage
10	23 Jul	3 Hy	42	Lowland	sedge
11	23 Jul	6 Hy	20	Lowland	K. bluegrass-northern reed
12	25 Jul	?	14	Lowland	sedge
13	26 Jul	?		Lowland	sedge
14	28 Jul	8	70	Upland	blue grama (hayed)
15	28 Jul	6	60	Upland	lead plant-rose
16	29 Jul	4	70	Midland	spiraea
17	31 Jul	4	42	Upland	lead plant
18	31 Jul	1	42	Upland	blue grama-green sage
19	4 Aug	12	70	Upland	blue grama
20	6 Aug	1	70	Lowland	sedge
21	8 Aug	10	70	Upland	willow
22	10 Aug	9	70	Lowland	sedge
23	10 Aug	5	70	Lowland	sedge
24	13 Aug	3	63	Midland	wild licorice-K. bluegrass
25	17 Aug	1	80	Upland	buckbrush
26	17 Aug	4	75	Midland	buckbrush-big bluestem
27	17 Aug	10	80	Upland	buckbrush-blue grama
28	27 Aug	7	80	Lowland	sedge (mowed)

Table 16. Prairie grouse brood habitat quality of six representative sites.

Brood Habitat Site Number	Habitat Type	Height-Density in decimeters		Dominant Plants
		100% VOM	0% VOM	
1	Upland	1.6	3.6	lead plant-rose
2	Midland	1.9	6.4	switchgrass
3	Midland	2.3	6.0	switchgrass-northern reed
4	Midland	2.4	6.6	switchgrass-willow
5	Lowland	1.8	5.0	sedge-switchgrass-northern reed
6	Lowland	1.9	6.3	sedge-willow

Table 17. Percent of readings at half decimeter of height-density pole 100% VOM at six representative brood habitat sites.

Half Decimeter	Brood Habitat Sites					
	#1 Upland	#2 Midland	#3 Midland	#4 Midland	#5 Lowland	#6 Lowland
0.0	0	0	0	0	0	0
0.5	5	0	0	0	0	0
1.0	30	3	0	5	15	5
1.5	25	30	9	12	27	30
2.0	25	52	44	25	42	55
2.5	12	10	31	30	12	10
3.0	3	5	16	20	4	
3.5				5		
4.0				3		
% at 1.5 dm or above	65	97	100	95	85	

1 dm=3.94

Table 18. Surface area of Habitat Types and Habitat Complexes.

Habitat Complex Habitat Type	Hectare	Acre	mi ²	Percentage
Hummocky Sandhills	26,505.4	65,494		50.16
Upland Grassland	13,917.2	34,389	53.7	26.34
Midland Grassland	6,701.0	16,558	25.9	12.68
Lowland Grassland	5,154.7	12,737	19.9	9.76
Cropland	732.5	1,810	2.8	1.39
Deltaic Plain	15,686.6	38,761		29.69
Midland Grassland	5,858.4	14,476	22.6	11.09
Lowland Grassland	2,180.1	5,387	8.4	4.13
Cropland	7,648.0	18,898	29.5	14.47
Choppy Sandhills	7,758.1	19,170		14.68
Upland Woodland	4,967.3	12,269	19.2	9.40
Open Grassland	2,792.8	6,901	10.8	5.29
River Terrace	2,887.5	7,135		5.46
Riparian Forest	2,310.8	5,710	8.9	4.37
Cropland	576.7	1,425	2.2	1.09

Data from Manske 1980.

Table 19. Habitat Use Index (% of bird locations/% of study area) for Sharptailed Grouse during annual phenological activities.

Habitat Complex Habitat Type	% of Sandhills	Spring 1 Apr-15 Jun	Summer 16 Jun-31 Aug	Fall 1 Sep-15 Nov	Winter 16 Nov-31 Mar
Hummocky Sandhills	50.16	1.98	1.79	1.62	0.34
Upland Grasslands	26.34	2.48	1.36	0.76	0.31
Midland Grasslands	12.68	2.33	2.57	4.62	0.03
Lowland Grasslands	9.76	0.34	1.96	0.20	0.08
Cropland	1.36	0.61	1.89	0.70	5.07
Shelterbelts	0.03	0.00	0.00	0.00	32.05
Deltaic Plain	29.69	0.00	0.08	0.53	2.16
Upland Grasslands	0.01	0.00	0.00	190.48	0.00
Midland Grasslands	11.09	0.00	0.03	0.09	0.42
Lowland Grasslands	4.13	0.00	0.48	3.11	0.00
Cropland	11.39	0.00	0.00	0.00	4.28
Shelterbelts	3.08	0.00	0.00	0.00	3.51
Choppy Sandhills	14.68	0.06	0.53	0.06	0.39
Upland Woodland	9.40	0.09	0.82	0.00	0.03
Open Grassland	5.29	0.00	0.00	0.18	1.01
River Terrace	5.46	0.00	0.00	0.00	0.00
Riparian Forest	4.37	0.00	0.00	0.00	0.00
Cropland	1.09	0.00	0.00	0.00	0.00
Transportation Routes					
Gravel Roads	0.52	0.00	0.00	3.66	0.00
(N)=		958	350	210	1248

Table 20. Habitat Use Index (% of activity sites/% of study area) for Sharptailed Grouse during annual phenological activities.

Habitat Complex Habitat Type	% of Sandhills	Display Ground Habitat	Nest Habitat	Brood Habitat
Hummocky Sandhills	50.16			
Upland Grasslands	26.34	2.76	0.00	1.56
Midland Grasslands	12.68	2.15	7.88	2.34
Lowland Grasslands	9.76	0.00	0.00	1.58
Cropland	1.36	0.00	0.00	0.00
Shelterbelts	0.03	0.00	0.00	0.00
Deltaic Plain	29.69			
Upland Grasslands	0.01	0.00	0.00	0.00
Midland Grasslands	11.09	0.00	0.00	0.00
Lowland Grasslands	4.13	0.00	0.00	0.69
Cropland	11.39	0.00	0.00	0.00
Shelterbelts	3.08	0.00	0.00	0.00
Choppy Sandhills	14.68			
Upland Woodland	9.40	0.00	0.00	1.17
Open Grassland	5.29	0.00	0.00	0.00
(N)=		88	8	28

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Visual Obstruction of Prairie Grouse Habitat Following Summer Mowing and Spring Burning

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1193

Vegetation on the highly productive subirrigated zone with the switchgrass community on the foot slope and the sedge meadow community on the toe slope grow very rapidly, produce a high density of seed heads, reach senescent growth stages early in the growing season, and these wet meadow graminoids deposit silicon crystals in their leaf epidermis which greatly increases the rate of wear on livestock teeth. These growth characteristics discourage livestock from grazing wet meadow vegetation during mid and late season which effectively transfers the grazing pressure to the upland mixed grass prairie and midland tall grass prairie communities resulting in under utilization on the lowland and heavier utilization on the upland and midland vegetation which is responsible for the great density of Kentucky bluegrass.

Manipulations of the wet meadow vegetation with summer mowing or spring prescribed burning returns the plants to early growth stages during the mid and late portions of the growing season. These early growth stages are highly nutritious (Erickson et al. 1978), low in epidermal silicon crystals, and readily selected for by livestock. Moving some of the grazing pressure back to the wet meadow returns grazing levels on the upland mixed grass prairie and the midland tall grass of big bluestem and little bluestem back to standard stocking rates.

Prairie grouse depend on the switchgrass community for nesting habitat and they use the switchgrass and the sedge meadow communities for roosting habitat and concealment cover.

Procedure

The effects of summer mowing and spring prescribed burning was evaluated for visual obstruction by the height-density pole method developed by Robel et al. (1970a) and modified by Kirsch (1974). A mean 100% VOM at 1.5 dm (5.9 in) was considered to be the minimum for good concealment cover (Manske 1981, Higgins and Barker 1982).

The summer mowing trial was conducted on wide areas of homogeneous switchgrass vegetation with the mowing treatments conducted during July and the height-density measurements read during May while the treatment was 1 to 6 years old.

The spring prescribed burn trial was conducted on two replicated areas of homogeneous switchgrass vegetation with the burns occurring during May. A control of unburned identical vegetation was adjacent to each burned area. The height-density measurements were read during May and October for 2 years post treatment.

Results

Summer Mowing Trial

The first spring following a summer mow treatment, the vegetation had a low 100% VOM at only 0.5 dm (2.0 in) (table 1) which was inadequate for concealment cover but if the mowed areas were adjacent to an existing upland display ground, some male birds could use the mowed area as courtship territories. During the second spring, the vegetation had already improved to a 100% VOM at 1.5 dm (5.9 in) which was at the minimum for good concealment cover and would most likely be used for day roosts, loafing areas, and brood travel routes. The third and fourth spring vegetation had good 100% VOM at 2.3 dm (9.1 in) and 2.7 dm (10.6 in) which would provide excellent concealment cover for nesting, night roosting, and escape cover for the prairie grouse. The fifth and sixth spring vegetation had greatly decreased to a 100% VOM at 1.8 dm (7.1 in) and 1.7 dm (6.7 in) which would still provide good concealment cover, just not as good as the vegetation during the third and fourth springs. The control area of unmowed and ungrazed had very similar 100% VOM during the fourth and fifth springs as the mowed treatment (table 1). Unmanipulated vegetation does not remain stagnant. It deteriorates. Undisturbed management is not a valid grassland management practice.

Spring Prescribed Burn Trial

The vegetation growth following a spring burn was slow to recover. During the first and second growing seasons, the 100% VOM remained below the minimum of a mean of 1.5 dm (5.9 in) and was well below the preburn 100% VOM at 1.9 dm, (7.5 in) and the level of the unburned control (table 2). The second year vegetation also would not provide the minimum for concealment cover and would most likely be used for day roosts, loafing areas, and brood travel routes, and would not be expected to be used for nesting, night roosting, or escape cover by prairie grouse.

Discussion

The treatments of summer mowing and spring prescribed burning did not effectively activate the four grass internal physiological growth mechanisms nor the ecosystem biogeochemical processes. Each of the treatments remove too much leaf area resulting in insufficient quantities of currently photosynthesized fixed carbon that would have supported new graminoid tiller growth. Counter to common assumptions, stored carbohydrates are not used for biomass growth to replace the leaf area removed during defoliation treatments (Richards and Caldwell 1985, Briske and Richards 1995). The benefit from the summer mowing and spring burning treatments for new regrowth biomass comes from the removal of standing old growth and senescent current years growth resulting in the reduction of shading which permits sunlight to reach the soil.

Removal of great proportions of the leaf area, causes both the summer mowing and spring burning treatments to reduce live graminoid tiller density. Coordination of these treatments with the grazing rotation schedule so that livestock will not have access to the treated vegetation until the grass tillers have developed to the 3.5 new leaf stage. At that growth stage, partial removal of leaf area by grazing can activate the four grass internal physiological growth mechanisms and the ecosystem biogeochemical processes that will increase graminoid tiller density.

Summer mowing attracts livestock to the wet meadow vegetation for one grazing season following treatment. Spring burning attracts livestock to the wet meadow vegetation for two grazing seasons following treatment. This difference of attracting livestock grazing of the wet meadow vegetation for one additional grazing season has been incorrectly used for the promotion of spring burning as being

more effective than summer mowing. However, the biological reason why the spring burning treatment attracts livestock grazing for two growing seasons is that burning causes greater degradation to the vegetation. This level of damage required two growing seasons for the plants to recover. The wet meadow vegetation treated with summer mowing was damaged less than that treated with spring burning and required only one growing season for the plants to recover.

Management Implications

Grazing graminivores have difficulty in properly defoliating the grassland communities that grow on subirrigated soils. The grasses and sedges that grow in the wet meadow community deposit silicate crystals in the leaf tissue, which cause excessive wear on livestock teeth. The mature wet meadow forage is usually consumed at only around a 10% rate. The ungrazed standing plant biomass restricts growth of young grass plants and this old material needs to be removed by summer mowing or spring burning on repeated cycles. However, the wet meadow experiences unpredictable wet and dry conditions of the subirrigated soils mandating a flexible treatment schedule. A simple strategy would be to organize the wet meadow areas into three groups. With each group containing wet meadow sites from each pasture of a grazing system. All of the wet meadow sites in the same group would receive treatment during the same year. All of the wet meadow sites in each group would receive a mowing or burning treatment one time in a cycle of three to five years as conditions permit. The sedge meadow can receive more frequent treatment than the switchgrass community.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.

Table 1. Mean visual obstruction during May for 6 years after summer mowing of Midland switchgrass community and control of no treatment.

Years Post Treatment	Mowed Once Grazed Each Year				Unmowed Ungrazed			
	0% VOM		100% VOM		0% VOM		100% VOM	
	dm	in	dm	in	dm	in	dm	in
1st	2.1	8.3	0.5	2.0	-	-	-	-
2nd	4.9	19.3	1.5	5.9	-	-	-	-
3rd	5.2	20.5	2.3	9.1	-	-	-	-
4th	6.3	24.8	2.7	10.6	7.5	29.6	2.6	10.2
5th	5.8	22.9	1.8	7.1	5.9	23.2	1.8	7.1
6th	5.7	22.5	1.7	6.7	-	-	-	-

1 dm=3.94 in

Table 2. Mean visual obstruction during spring and fall for two years after prescribed burn of Midland switchgrass community and control of no burn.

Years Post Treatment	Spring Burn				No Burn			
	0% VOM		100% VOM		0% VOM		100% VOM	
	dm	in	dm	in	dm	in	dm	in
1 st Spring	0.0	0.0	0.0	0.0	4.5	17.7	1.9	7.5
1 st Fall	5.7	22.5	1.5	5.9	6.5	25.6	2.3	9.1
2 nd Spring	5.2	20.5	1.4	5.5	6.2	24.4	1.9	7.5
2 nd Fall	4.5	17.7	1.7	6.7	5.6	22.1	2.0	7.9

1 dm=3.94 in

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Undisturbed Management of Grassland Habitat Is Not A Biologically Sustainable Treatment

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1194

The standard go to recommended grassland habitat management for wildlife, scarce plants, and precarious insects is the undisturbed treatment. This report scientifically explains why the undisturbed treatment of grassland habitat is not biologically sustainable in the Northern Plains.

Often times, livestock grazing is removed to protect a grassland ecosystem based on naive presumptions that livestock grazing causes damage to a grassland ecosystem or that they interfere with the life cycle of wildlife, scarce plants, and precarious insects. Livestock grazing is not what causes damage to grasslands; poor management of grazing livestock can cause serious damage to grasslands. The greatest antagonistic effects to a grassland ecosystem occur from undisturbed management concepts that rest grasslands from grazing defoliation. The term “rest” is a misnomer; resting a grassland does not cause revitalizations of crucial biological and ecological processes. Resting a grassland by withholding partial defoliation by grazing results in regression of ecosystem processes and biological growth mechanisms. Several negative changes occur relatively soon after grazing graminivores are removed from grasslands; the live root biomass of grasses decrease (Whitman 1974), standing dead leaves and litter accumulate (Brand and Goetz 1986), and ecosystem biogeochemical processes diminish (Manske 2011b).

The reduction of live root surface area causes a decrease in active root length for interaction with symbiotic rhizosphere organisms and causes a decrease in absorption of water and nutrients from the soil. Reduction of active root biomass and diminishment of grass plant health vigor result in a loss of resource uptake efficiency and a suppression of competitiveness of grass plants to take up mineral nitrogen, essential elements, and soil water (Kochy 1999, Kochy and Wilson 2000).

Grass plants produce double the quantity of leaf biomass than needed for normal plant growth and maintenance (Crider 1955, Coyne et al. 1995). Without grazing graminivores to remove the surplus

herbage production, the standing leaf material accumulates rapidly and changes from an asset to a detriment. The accumulation of nondefoliated live and standing dead leaves of grasses reduce light penetration below native grass light saturation points (Peltzer and Kochy 2001). Native grasses have high light saturation points and require near full sunlight. Warm season grasses have higher light saturation points than cool season grasses (Kochy 1999, Kochy and Wilson 2000). Shading reduces native warm season grasses more than native cool season grasses. Introduced cool season domesticated grasses have lower light saturation points than native grasses, permitting domesticated grass to live in low light conditions. The accumulating standing dead leaves shade the lower leaves, increasing the rate of leaf senescence and reducing the rate of photosynthesis, causing a decrease in the supply of carbohydrates (Coyne et al. 1995) that results in a reduction in growth of leaves and roots (Langer 1972, Briske and Richards 1995). Grass leaves grown under shaded conditions become longer but narrower, thinner, and lower in weight (Langer 1972) than leaves in sunlight. Shaded grass plants shift to erect growth forms with a small number of tillers (Briske and Richards 1995). Lack of grazing reduces grass tiller densities by decreasing tiller development and increasing tiller mortality through shading (Manske 2013). After a few years, shading reduces the composition of native grass species in the ecosystem and increases the composition of shade-tolerant or shade-adapted replacement species, like smooth brome grass and Kentucky bluegrass.

Standing dead material not in contact with soil does not decompose through microbial activity. Dead plant material on nongrazed treatments breaks down slowly over several years by leaching and weathering and builds up into a thick mulch layer. Thick mulch effectively blocks sunlight from reaching understory young grass leaves. Thick mulch modifies soil temperatures. Thick mulch ties up and holds organic nutrients above the soil surface preventing accession to the soil organic matter which limits nutrient cycling through biogeochemical processes increasing the deficiencies of essential

elements causing great reductions in grass growth of leaves and roots. Thick mulch absorbs and holds precipitation for later evaporation preventing the water from infiltrating into the soil diminishing soil water to deficiency quantities (Wright and Bailey 1982, Manske 2000, 2011a).

The loss of active root length is a contributing factor in the reduction of rhizosphere biomass. The primary cause for the reduction in rhizosphere biomass is, however, the great reduction in the quantity of carbohydrate energy exudated from the grass roots into the rhizosphere zone. Without partial defoliation by grazing, only a small quantity of short carbon chain energy leaks from the grass roots into the rhizosphere; this low amount of simple carbon compounds is barely enough to sustain a very small rhizosphere microbe biomass. A small biomass of rhizosphere organisms function at greatly reduced rates of organic material decomposition, and can mineralize only small quantities of nitrogen and other essential elements (Anderson et al. 1981, Coleman et al. 1983, Curl and Truelove 1986, Klein et al. 1988, Whipps 1990).

Removal of partial defoliation for 13 years resulted in an increase of standing dead and litter, an increase of introduced domesticated grasses, a great decrease of native grasses, and an increase of all forbs with a decrease in desirable forbs (Manske 2012). The total dead biomass was 63.6% of the total herbage biomass (an increase of 300.3%), with standing dead at 26.9% and litter at 36.7%. Live herbage biomass was 36.4% of the total herbage biomass, with domesticated grass at 64.8% (an increase of 94.8%), cool season grasses at 2.7% (a decrease of 89.0%), warm season grasses at 0.6% (a decrease of 79.4%), upland sedges at 22.9% (a slight decrease of 1.5%), and all types of forbs at 9.0% (an increase of 56.3%). The rhizosphere biomass had decreased to 52.2 kg/m³ which can mineralize less than 20% of the minimum quantity of mineral nitrogen needed at 100 lbs/ac (112 kg/ha).

Removal of partial defoliation by grazing for 75 years resulted in an excessive increase of standing dead and litter, a remarkable increase of woody shrubs and trees, an increase of introduced domesticated grasses, a severe reduction of native grasses, and a considerable decrease of desirable forbs (Manske 2013). The total dead biomass was 59.7% of the total herbage biomass (an increase of 263.6%), with standing dead at 11.1% and litter at 48.6%. Live herbage biomass was 40.3% of total herbage biomass, with domesticated grass at 79.6% (an increase of 106.1%), cool season grasses at 5.7%

(a decrease of 80.0%), warm season grasses at 0.04% (a decrease of 99.7%), upland sedges at 6.3% (a decrease of 23.9%), and all types of forbs at 8.4% (an increase of 20.0%). The woody shrubs and trees had increased 500.0% and occupied 53.8% of the land area. The grass root biomass had decreased 32.6%. The available mineral nitrogen was only at 42.0 lbs/ac (47.0 kg/ha) which is greatly below the needed minimum of 100 lbs/ac (112 kg/ha).

The huge increase of woody shrubs and trees was not caused by the lack of fire. It was caused by the lack of biologically effective grazing management that resulted in the great reduction of the grass plant mechanism of competitive nutrient and water resource uptake. When grass plants are managed biologically they become healthy and have the full competitive resource uptake mechanism working, seedlings of trees, shrubs, forbs, and introduced grasses cannot become established in mixed grass prairie communities (Li and Wilson 1998, Kochy and Wilson 2000, Peltzer and Kochy 2001).

With continued ecosystem degradation, the impeded native grasses declined further in their ability to be competitive in uptake of belowground resources of soil water and nutrients (Li and Wilson 1998, Kochy and Wilson 2001), causing additional mortality of native grasses and decreased density, resulting in the creation of numerous shaded bare spaces in the previously closed prairie plant communities (Manske 2013).

Opportunistic introduced cool season domesticated grasses, like Kentucky bluegrass and smooth brome grass can exist under low light conditions and invade the shaded bare spaces by procuring the remaining belowground resources not being taken up by the diminutive, low vigor native grasses (Kochy and Wilson 2000). These domesticated grasses also have labile roots that breakdown easily making the nutrients contained in dead material readily available to support continued growth and expansion of these nonnative grasses without assistance from soil microorganisms. In a short period of time, the introduced domesticated grasses increase in density and herbage biomass creating greater shading problems for the suppressed native grasses, escalating degradation of an already devastated ecosystem.

With the removal of partial defoliation by grazing there is a great reduction in the quantity of carbohydrates exuded from the grass roots into the rhizosphere zone. The rhizosphere microorganism biomass and activity are dependent on access to

outside sources of simple carbon chains from the grasses. The rhizosphere microflora trophic levels lack chlorophyll and have low carbon (energy) content. Partial defoliation of grass plants at vegetative phenological growth stages by large graminivores cause great quantities of exudates containing simple carbon compounds to be released through the plant roots into the rhizosphere zone. When that source of carbon stops, the small amount of carbon compounds in the plant material that leaks from grass roots is barely enough to sustain a very small rhizosphere biomass that cannot mineralize the minimum quantity of 100 lbs/ac of mineral nitrogen causing great reductions in herbage biomass production.

Grazing graminivores perform several indispensable functions for grassland ecosystems. Partial defoliation by grazing graminivores activate the four major internal grass plant growth mechanisms, enhance rhizosphere microorganisms activity and increase their biomass large enough to perform the ecosystem biogeochemical processes and to mineralize greater than 100 lbs/ac of mineral nitrogen plus the other essential elements, and they remove the surplus grass leaf biomass produced by grass plants before it can become a detriment to the ecosystem each growing season.

Grazing graminivores is biologically beneficial for grass plants and for grassland ecosystems when grazing periods are coordinated with grass phenological growth stages. The four primary physiological growth mechanisms within grass plants that perform the herbage replacement processes are activated with partial defoliation by grazing graminivores when 25% to 33% of leaf weight is removed from 60% to 80% of lead tillers during vegetative phenological growth stages between the three and a half new leaf and the flower stage when a threshold quantity of 100 lbs/ac of mineral nitrogen is available. Unavailable soil organic nitrogen must be mineralized by soil microbes in order for nitrogen to be usable by grass plants. A large biomass of rhizosphere microorganisms is required to mineralize a large quantity of nitrogen yielding 100 lbs/ac. Grassland microbes are achlorophyllous and cannot fix their own carbon energy. Large quantities of surplus short chain carbon energy are produced by healthy vegetative lead tillers that can be exudated into the microbial rhizosphere when 25% to 33% of the leaf weight is removed with partial defoliation by grazing graminivores while lead tillers are between the three and a half new leaf stage and the flower stage. The four primary physiological growth mechanisms are

not functional when less than 100 lbs/ac of mineral nitrogen is available and are not activated when zero % or greater than 33% of the leaf weight of lead tillers is removed during vegetative growth stages.

Grazing graminivores receive nutritious forage from healthy grass plants. However, providing forage for graminivores is not the only purpose for grazing grasslands. Grass plants have biological requirements and have four primary physiological growth mechanisms that must be activated by partial defoliation by grazing. Rhizosphere microorganisms are needed in large quantities to perform all of the ecosystem biogeochemical processes, but are unable to fix carbon energy and require exudated short chain carbon energy that can be provided by partial defoliation by grazing. The three indispensable biotic components of grasslands; grass vegetation, rhizosphere organisms, and large graminivores; must have their biological requirements provided with partial defoliation by grazing graminivores in order for grassland ecosystems to function at achievable levels.

The successful sustainability of grassland ecosystems depends upon the implementation of biologically effective management strategies that can provide the biological and physiological requirements of the forage grass plants, soil microorganisms, and grazing graminivores, that can activate and maintain the grass plant growth mechanisms and the ecosystem biogeochemical processes, that can revitalize soil structure and functionality, that can increase forage growth and nutritional quality, and that can improve livestock growth and weight performance along with the capture of greater wealth per acre.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript.

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Deferred-Rotation: An Obsolete Grazing Practice

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1195

The current science of rangeland management has been built by countless, hardworking, dedicated scientists that have inspired deeper investigations into how rangeland ecosystems work. The concept of deferred and rotation grazing was developed on an early hypothesis that considered the only process to improve degraded native rangeland was to reseed the land by mechanical methods or by letting the grass plants produce seeds and trample the seeds into the ground with livestock (Jardine 1916). Modern more profound hypothesis consider improvement of degraded native rangeland by activating the processes of vegetative reproduction of secondary tillers from axillary buds and by increasing the biomass of the symbiotic rhizosphere microorganisms that perform the ecosystem biogeochemical processes (Manske 2018) making the deferred-rotation grazing practices obsolete.

Vegetative tiller growth is the dominant form of reproduction in semiarid and mesic grasslands (Belsky 1992, Chapman and Peat 1992, Briske and Richards 1995, Chapman 1996, Manske 1999a) not sexual reproduction and the development of seedlings. Recruitment of new grass plants developed from seedlings is negligible in grassland ecosystems. The frequency of true seedlings is extremely low in functioning grasslands, and establishment of seedlings occurs only during years with favorable moisture and temperature conditions (Wilson and Briske 1979, Briske and Richards 1995), in areas of reduced competition from vegetative tillers, and when resources are readily available to the growing seedling.

The deferred-rotation grazing system was developed by Arthur Sampson from research conducted in the Blue Mountains of Oregon. The first version was a two pasture system with one pasture grazed early and one pasture deferred until late season, then rotated the order on a one or two year cycle (Sampson 1913). The second version was a three pasture system with grazing separated into spring, summer, and fall. The sequence was followed for two years, during the rotation cycle, the fall pasture became the spring pasture, the previous spring pasture became the summer pasture, and the

previous summer pasture became the fall pasture (Sampson 1923). The intended purpose of deferment was to gain plant vigor, increase seed production, storage of carbohydrates in roots and stems, and improve the health of rangeland. Grazing after seed maturity would scatter and trample the seeds into the soil in order to promote seedling establishment. The second year of deferment was intended to improve development of young seedlings.

Two years of deferment was explained by Sampson (1914), "The grazing has been deferred until the fall for two years. This is done to allow any seedlings that might start from the previous year's seeding a chance to become more firmly established before the division (pasture) is grazed."

Sampson (1913, 1914) and Jardine (1916) knew that grass seed that drops from the grass head and germinate have an extremely low survival rate because they do not get enough root material into the soil before they dry out. So the late season trampling by cattle seemed to be the only logical way to get the dropped seeds too the soil. They did not think one year would be enough, so they extended the process to two years.

The Blue Mountains of Oregon where Sampson collected data is spectacular country, however, the seasonal precipitation distribution is the Pacific Pattern with most of the precipitation occurring during fall and winter. The fall rains begin in late September and increase with a peak in November or December and decrease to March, with July, August, and early September receiving very little precipitation. This pattern greatly limits available soil moisture for developing grass roots during the growing season. Sampson would have experienced very little grass growth and nearly no grass regrowth during the summer months. The grasses of Oregon produce vegetation tillers, but because of the lack of rainfall during summer, they are usually inhibited by low soil water to grow during that growing season. The grazing activated vegetative secondary tillers appear the next spring, a month or more ahead of normal lead tiller development. Sampson did not recognize these early

spring tillers as last grazing season stimulated vegetative tillers. At that time, pasture scientists, were trained as agronomists, knew that some grasses produced vegetative tillers. However, the importance of vegetative tillers was dismissed. Grass seed production and seedling establishment was far more important for the improvement of pasture forage production according to the agronomic based scientific concepts of the time.

A deferred and rotation grazing treatment was investigated at the Northern Great Plains Field Station at Mandan, North Dakota (Sarvis 1923, 1941). The experimental plan followed closely, with modifications, to the grazing order of a three pasture deferred and rotation practice described in the 1915 Agricultural Yearbook (Jardine 1916). This deferred-rotation treatment was added to the two year old stocking rate on seasonlong grazed pastures study that had four rates of grazing intensities. These grazing investigations were conducted by J.T. Sarvis for 23 years from 1918 to 1940. The modifications made by Sarvis (1923) was the change in the pasture sequence of the pasture with the fall deferred treatment moved to the summer period, which was different than Sampson's plan which moved the fall deferred treatment to the spring period (Sampson 1923).

Sarvis (1941) believed that undergrazing caused slight deterioration to plant communities by the accumulation of old vegetation that steers would not eat and by the increase of coarseness of weeds. Sarvis (1941) also knew that continued removal of the maximum quantity (100%) of the annual forage produced would sooner or later cause a sharp decline in grazing capacity. As a result, Sarvis developed grazing guidelines that required that 15% to 25% of the annual forage production to remain standing at the end of the grazing season. However in practice, the reported mean forage use on the deferred pastures was 92% removed and the mean forage use on the standard seasonlong pasture was 77% removed (Sarvis 1923).

The grazing investigations conducted by J.T. Sarvis (1923, 1941) at the Mandan, North Dakota, Northern Great Plains Field Station studied the three pasture deferred and rotation grazing treatment that was developed by Sampson (1913, 1923), and adapted and put into practice by the US. Forest Service (Jardine 1916), in order to determine the performance of its direct application in the northern Great Plains. The study area was a large section of flat land with very good soil and uniform mixed grass prairie in excellent condition, 3.5 miles south of Mandan. Seventy acres were divided into three equal

pastures to be grazed during spring, summer, and fall periods. A comparable control treatment was seventy acres in one pasture grazed seasonlong. The intended grazing season was 150 days from mid May to mid October (table 1). The research animals were two years old grade steers of standard beef breeds of Angus, Herefords, and Shorthorns that were furnished by the North Dakota Agricultural Experiment Station with the mean initial weight of 750 pounds.

When the steers on the grazing treatments appeared to have lost weight, they were weighed at 5 or 10 day intervals and when the weight loss was documented the steers on the seasonlong treatments were removed from the study pastures and moved to the reserve pasture. When forage on the fall pasture of the deferred treatment became short and inferior and the steers began to lose weight, the steers were moved to the spring pasture that had new secondary growth (Sarvis 1941). This new secondary growth was not recognized as vegetative reproduction of tillers from axillary buds.

During the first two years of the deferred treatment, 10 steers grazed the deferred and seasonlong treatments at the same stocking rate. However, the steers on the deferred treatment gained a mean of only 260 pounds which was much less weight than the steers on the seasonlong treatment that gained a mean of 309 pounds. The number of steers placed on the deferred treatment was increased to an average of 14 head and the number of steers on the seasonlong treatment remained at 10 head. However, after 17 years the mean weight gain per head on the deferred treatment reached 266.1 pounds and the gain per head on the seasonlong treatment dropped to 308.3 pounds (table 2).

The lower weight gain for the steers on the deferred treatment (table 3) were explained by Sarvis (1923), "The deferred and rotation pastures show either light gains or losses for the month of October and somewhat reduced gains during September. The lower gains during the latter part of the season do not necessarily condemn fall grazing. This is the time when cattle put on the "finish" so often referred to by stockmen, which is apparently a hardening process brought about through a reduction in the quantity of water that they drink, as well as a change in the condition of their flesh. Therefore, when cattle are without feed or water for 24 hours in the fall they will "shrink" less than they would during the same length of time earlier in the season. The autumn also represents the transition or adjustment period of the cattle between summer and winter. The cooler

weather of autumn always causes shrinkage of the cattle, which is recorded as a loss in weight.”

Sarvis failed to explain why the steers on the seasonlong treatment did not experience the same degree of “finish” as the steers on the deferred pasture (table 3).

Sarvis (1923) explained the purpose of the deferment, “This deferred and rotation grazing system is designed to allow each division of the pasture to mature a crop of seeds for two successive years before it is harvested by the cattle in the fall of each year. Grazing on each division is deferred and rotated, so that each unit has an equal chance to produce a maximum crop of seeds normally before it is distributed by grazing. The seeds of the grasses which are scattered on the ground are aided in their planting by trampling of the cattle.

Sarvis (1941 p.80) concluded, “So far as it has been possible to determine, there has been no significant benefit from reseeding of the grasses under this deferred and rotation grazing system during this experiment after 23 years.”

Sampson knew very early in his studies that cattle produced very low weight gains on the deferred pastures, he knew that some grasses reproduced vegetatively, and he did not have documentation that the production of seeds resulted in greater numbers of seedlings.

The US Forest Service knew that cattle produced very low weight gains on the deferred pastures, and they did not have documentation that the production of seeds resulted in greater numbers of seedlings.

Sarvis knew in the first two years of study that two year old steers produced very low weight gains on the deferred pastures, he documented that the number of seedlings did not increase on the deferred treatment, and he documented a large reduction in grass density that he attributed to the severe drought frequency during the study period with 4 of the driest years recorded including 1934 and 1936. Sarvis did not consider the high forage use at 85% to 75% to be a factor in grass density reduction.

Despite the lack of supporting scientific data, these pasture agronomists still continued to promote the use of the deferred-rotation grazing practice to livestock producers west of the Mississippi River.

The deferred-rotation grazing practice was included in a study of the effects of grazing management practices on grassland vegetation and on the quantity of prairie grouse concealment cover of the Sandhills region in southeastern North Dakota that evaluated for visual obstruction by the height-density pole, herbage biomass by hand clipping, and basal cover by the ten pin point frame conducted by Manske, 1975 to 1980.

The seasonlong grazing treatment resulted in a mean 100% VOM of the switchgrass zone at 1.5 dm (5.9 in) with 55% readings at or above 1.5 dm during spring, 13% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plant species composition significantly increased with Kentucky bluegrass, and decreased with warm and cool season native grasses.

The deferred grazing treatment resulted in a mean 100% VOM of the switchgrass zone at 1.6 dm (6.3 in) with 62% readings at or above 1.5 dm during spring, 20% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and the plants species composition significantly increased with Kentucky bluegrass, and decreased with switchgrass, warm and cool season native grasses, and upland sedges.

The twice-over rotation grazing strategy resulted in a mean 100% VOM of the switchgrass zone at 2.0 dm (7.9 in) with 78% readings at or above 1.5 dm during spring, 32% of the herbage biomass samples from the Upland and Midland communities were greater on the grazed area than on the ungrazed area, and plant species composition significantly increased with switchgrass, lowland sedges, warm and cool season native grasses, upland sedges, and total basal cover.

Grassland ecosystems of the Sandhills region were negatively affected by the deferred grazing practice from the significant yearly increase in Kentucky bluegrass and a decrease in native warm and cool season grass basal cover, total grass density, herbage biomass production, and low quality of prairie grouse concealment cover. The grassland ecosystems received a huge loss of significant energy and resources which were used for the increased useless grass seed production that could have been supplied for an increase of vegetative secondary tiller production with adequate crude protein for lactating cows to graze until mid October.

Deferring the starting date of grazing on native rangeland until after the grass lead tillers have flowered and developed seeds prevents stimulation of compensatory physiological mechanisms, vegetative reproduction by tillering, competitive nutrient resource uptake, and water use efficiency mechanisms within grass plants, and rhizosphere organism activity that perform all of the ecosystem biogeochemical processes. The herbage biomass available to grazing livestock on deferred grazing practices is below the potential quantities (Manske 2000b) and the nutritional quality is below the crude protein requirements of lactating cows (Whitman et al. 1951, Manske 1999b) because of leaf senescence and translocation of cell constituents from leaf structures (Langer 1972, Beard 1973, Leopold and Kriedemann 1975). The intended biological purpose of deferred grazing was to increase grass density by promoting seedling development from increased seed stalk quantities and to use trampling by livestock to scatter and plant the produced seeds. However, grassland ecosystem processes do not function in accordance with the obsolete deferred grazing hypothesis.

Effects on cow and calf weight performance from three grazing management strategy concepts were evaluated for five years (1983-1987) in western North Dakota on native rangeland mixed grass prairie conducted by Manske.

The old management concept of deferred grazing until after seed set was stocked heavily at 8.88 ac/AU and 2.22 ac/AUM for 4.0 months from 16 Jul to 15 Nov (122 days) (table 4).

The traditional concept of seasonlong grazing was stocked at 12.31 ac/AU and 2.80 ac/AUM for 4.39 months from 18 Jun to 30 Oct (134 days) (table 4).

The biologically effective concept of three pasture twice-over rotation strategy was stocked at 10.22 ac/AU and 2.28 ac/AUM for 4.49 months from 1 Jun to 16 Oct (137 days) (table 4).

On the deferred treatment, calf weight gain was only at 1.80 lbs per day, 24.73 lbs per acre, and accumulated weight gain was low at 219.60 lbs per head. Cow weight gain was extremely low at 0.06 lbs per day, 0.82 lbs per acre, and accumulated weight gain was 7.24 lbs per head (tables 5 and 6).

On the traditional seasonlong treatment, calf weight gain was 2.18 lbs per day, 23.77 lbs per acre, and accumulated weight gain was 292.12 lbs per head. Cow weight gain was 0.40 lbs per day, 4.35 lbs

per acre, and accumulated weight gain was 53.60 lbs per head (tables 5 and 6).

On the biologically effective twice-over strategy, calf weight gain was 2.21 lbs per day, 29.63 lbs per acre, and accumulated weight gain was 302.80 lbs per head. Cow weight gain was 0.62 lbs per day, 8.31 lbs per acre, and accumulated weight gain was 84.91 lbs per head (tables 5 and 6).

Dollar value captured on the deferred treatment was the lowest. Pasture cost was low at \$77.79 and cost per day was low at \$0.64 because of the very heavy stocking rate (table 4). Pasture weight gain value was low at \$153.72, net return per cow-calf pair was very low at \$75.93 because of the low calf weight gain, net return per acre was moderate at \$8.55 because of the heavy stocking rate, and the cost per pound of calf weight gain was high at \$0.51 per lb because of the low calf gains (tables 5 and 6).

Dollar value captured on the traditional seasonlong treatment was moderate. Pasture cost was high at \$107.84 and cost per day was high at \$0.80 because of the low stocking rate (table 4). Pasture weight gain value was high at \$204.48, net return per cow-calf pair was high at \$96.64, net return per acre was low at \$7.85 because of the low stocking rate, and the cost per pound of calf weight gain was low at \$0.37 per lb because of the good calf gains (tables 5 and 6).

Dollar value captured on the biologically effective twice-over strategy was good. Pasture cost was moderate at \$89.53 and cost per day was low at \$0.65 (table 4). Pasture weight gain value was high at \$211.96, net return per cow-calf pair was very high at \$122.43, and net return per acre was very high at \$11.98, and the cost per pound of calf weight gain was very low at \$0.30 per lb (tables 5 and 6).

The crude protein content of grass lead tillers drops below the requirements of a lactating cow during the last two weeks of July (Whitman et al. 1951, Manske 1999b). The cow weight gain per day begins to decrease during early August on the deferred and seasonlong grazing practices (table 6) and those cows lose weight after mid September. The calf weight gain per day begins to decrease two week after their cows decrease in weight gain on the deferred and seasonlong grazing practices (table 6).

The grazing cows on the twice-over rotation strategy stimulate vegetative reproduction of secondary tiller development from the axillary buds during the first grazing period from 1 June to 15 July.

These secondary tillers provide adequate crude protein to meet the lactating cows requirements through September on table 6. During these early years of development of the twice-over system, it was hypothesized that the tiller stimulation period lasted until the end of July. It did not, it lasts until mid July. As a result the third pasture did not grow secondary tillers and the cows lost weight during early October (table 6). When the stimulation period was adjusted to mid July, the third pasture produced secondary vegetative tillers high in crude protein, and the cows gained weight until mid October. Mid October is the latest that grass plants can be pushed to maintain adequate levels of crude protein that meets lactating cow requirements. Notice the jump in cow and calf weight gain on the twice-over practice in early August when the old second grazing period previously started. With the adjustment in the stimulation period, the first grazing period on all pastures is 45 days long from 1 June to 15 July and the second period is 90 days long from 15 July to 14 October. The grassland ecosystem improves and cow and calf weight gains increase because of the grazing stimulated vegetative reproduction of secondary tillers from axillary buds that contain adequate quantities of crude protein to meet the requirements of lactating cows until mid October.

Biologically effective management of native rangeland meets the biological and physiological requirements of the grass plants, soil organisms, and grazing animals, and cycles the essential elements. The biologically effective twice-over rotation grazing management strategy coordinates defoliation events with grass phenological growth stages and activates the compensatory physiological mechanisms, the vegetative reproduction by tillering mechanisms, the nutrient resource uptake mechanisms, and the water use efficiency mechanisms within grass plants, and elevates the soil rhizosphere microorganism biomass that perform all of the ecosystem biogeochemical processes.

An early hypothesis that had a biologically incomplete concept of how grassland ecosystems function required reseeding to restore degraded grasslands was used to develop the deferred-rotation grazing practice. However, the concept that recruitment of new plants on grassland ecosystems comes from seedlings was obsolete. New grass plants develop from vegetative secondary tillers. Because of the early pasture scientists dismissed the importance of vegetative tillers, the deferred grazing practices caused further ecosystem degradation and poor livestock weight gains. The deferred practices does not increase grass seedling establishment, and vegetative tillers are inhibited, causing a decrease in native grass density, providing spaces for Kentucky bluegrass and other weeds to increase. The resulting available late season forage is senescent lead tillers, dried Kentucky bluegrass, and coarse mature weeds that contain crude protein at levels well below the requirements of lactating cows causing extremely poor weight gain performances from cows and calves.

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript and for development of the tables.

Table 1. Summer grazing period, stocking rate, and pasture costs (rent at \$8.76/ac) on the deferred and seasonlong treatments conducted by J.T. Sarvis, 1918-1934.

Management Strategy Concept	Grazing Period	# Days	# Months	Acres per 2 yr Steer	Acres per Month	Pasture Cost \$	Cost per day \$
Deferred	16 May-8 Oct	146	4.79	5.0	1.04	43.80	0.30
Seasonlong	16 May-10 Oct	148	4.85	7.0	1.44	61.32	0.41

Based on Data from Sarvis 1941.

Table 2. Summer two year old steer weight performance and net returns (at market value of \$0.70/lb) on the deferred and seasonlong treatments conducted by J.T. Sarvis, 1918-1934.

Management Strategy Concept	Gain per Head lbs	Gain per Day lbs	Gain per Acre lbs	Pasture Weight Gain Value \$	Net Return per Steer \$	Net Return per Acre \$	Cost/lb Steer Gain \$
Deferred							
Steer	266.1	1.82	53.2	186.27	142.47	28.49	0.17
Seasonlong							
Steer	308.3	2.08	44.0	215.81	154.49	22.07	0.20

Based on Data from Sarvis 1941.

Table 3. Two year old steer gain per head and gain per day during grazing season on native rangeland managed by deferred and seasonlong treatments conducted by J.T. Sarvis, 1918-1934.

2 yr Steer	16 May-30 Jun Spring	1 Jul-31 Aug Summer	1 Sep-15 Oct Fall	16 May-15 Oct Season
Deferred				
Gain/Head	135.8	110.5	19.8	266.1
Gain/Day	2.95	1.78	0.44	1.82
Seasonlong				
Gain/Head	154.5	119.2	34.6	308.3
Gain/Day	3.36	1.92	0.77	2.08

Data from Sarvis 1941.

Table 4. Summer grazing period, stocking rate, and pasture costs (rent at \$8.76/ac) on the deferred, seasonlong, and twice-over treatments in western North Dakota conducted by L.L. Manske, 1983-1987.

Management Strategy Concept	Grazing Period	# Days	# Months	Acres per C-C pr	Acres per AUM	Pasture Cost \$	Cost per Day \$
Deferred	16 Jul-15 Nov	122	4.0	8.88	2.22	77.79	0.64
Seasonlong	18 Jun-30 Oct	134	4.39	12.31	2.80	107.84	0.80
Twice-over	1 Jun-16 Oct	137	4.49	10.22	2.28	89.53	0.65

Table 5. Summer calf and cow weight performance and net returns (at market value of \$0.70/lb) on the deferred, seasonlong, and twice-over treatments in western North Dakota conducted by L.L. Manske, 1983-1987.

Management Strategy Concept	Gain per Head lbs	Gain per Day lbs	Gain per Acre lbs	Pasture Weight Gain Value \$	Net Return per C-C pr \$	Net Return per Acre \$	Cost/lb Calf Gain \$
Deferred							
Calf	219.60	1.80	24.73	153.72	75.93	8.55	0.51
Cow	7.24	0.06	0.82				
Seasonlong							
Calf	292.12	2.18	23.73	204.48	96.64	7.85	0.37
Cow	53.60	0.40	4.35				
Twice-over							
Calf	302.80	2.21	29.63	211.96	122.43	11.98	0.30
Cow	84.91	0.62	8.31				

Table 6. Calf and cow gain per day during biweekly periods grazing native rangeland managed by three systems in western North Dakota conducted by L.L. Manske, 1983-1987.

Calf	Jun	Jul	Aug	Sep	Oct	Nov			
Deferred		2.39	2.39	2.23	2.09	2.09	1.04	0.77	0.77
Seasonlong	2.52	2.50	2.22	2.34	2.44	2.30	1.87	1.61	1.40
Twice-over	2.61	2.06	2.25	2.27	2.55	2.50	2.18	2.06	1.44
Cow	Jun	Jul	Aug	Sep	Oct	Nov			
Deferred		1.52	1.49	0.71	0.15	-0.19	-0.55	-0.74	-1.01
Seasonlong	1.97	1.78	1.10	0.95	0.20	0.07	-0.38	-0.81	-0.74
Twice-over	3.04	2.17	0.70	0.52	0.79	0.89	0.84	0.54	-1.68

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Grassland Wildlife Habitat Management Compatible with Livestock Production in the Northern Plains

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1187

Traditionally, livestock grazing and wildlife habitat were considered to be competing uses of grasslands. But that was when management practices focused only on the aboveground component of grass.

Fortunately, the long needed basic science of the critical grass physiological growth mechanisms and the essential grassland ecosystem biogeochemical processes performed by soil microbes were described in detail during a concentrated effort in the late 1970's through the 1990's. These important research findings were not reported on the 6 o'clock news nor in the popular farm magazines and the general public has remained unaware of the existence of this paradigm changing breakthrough science. Knowledge of the grass growth mechanisms and ecosystem biogeochemical processes permits development of management strategies that consider all the above - and belowground components while meeting the biological requirements of the grass plants and soil microbes and enhancing the functionality of the ecosystem resulting in grassland productivity at biological potential levels. Biologically effective management strategies that are designed to activate the grass physiological growth mechanisms and promote the ecosystem biogeochemical processes is also sound livestock grazing management and beneficial wildlife habitat management.

Grasslands are complex ecosystems; exceedingly more complex than the most complicated machines ever built by humans. Grassland ecosystems are comprised of biotic and abiotic components. The indispensable biotic components are grass vegetation, rhizosphere organisms, and domesticated graminivores which have biological and physiological requirements (Manske 2018b, c, d). The abiotic components include radiant energy from sunlight, the major essential elements of carbon, hydrogen, nitrogen, and oxygen, and the minor essential elements of macro - and micro - nutrients required by living organisms, and the environmental conditions. Grass plants, rhizosphere organisms, and grazing graminivores have developed complex symbiotic relationships. Grazing graminivores

depend on grass plants for nutritious forage. Grass plants depend on rhizosphere organisms for mineralization of essential elements from the soil organic matter. Rhizosphere organisms, which are achlorophyllous, depend on grass plants for short chain carbon energy that is exudated through the roots of lead tillers at vegetative growth stages following partial defoliation by grazing graminivores. Grass plants produce double the leaf biomass than is needed for photosynthesis in order to attract the vital partial defoliation by grazing graminivores on which they depend.

The indispensable grass vegetation provides nutritious forage to large grazing graminivores and habitat to wildlife. Grass plants use the major and minor essential elements in the inorganic form to synthesize vital organic components of carbohydrates, proteins, and nucleotides for growth. Grass plants have four primary internal plant growth mechanisms that help grass tillers withstand and recover from partial defoliation by grazing graminivores. The primary mechanisms are: compensatory physiological mechanisms (McNaughton 1979, 1983; Briske 1991); vegetative reproduction by tillering (Mueller and Richards 1986, Richards et al. 1988, Murphy and Briske 1992, Briske and Richards 1994, 1995); nutrient resource uptake (Crider 1955, Li and Wilson 1998, Kochy and Wilson 2000, Peltzer and Kochy 2001); and water use efficiency (Wight and Black 1972, 1979).

Compensatory physiological mechanisms give grass plants the capability to replace lost leaf and shoot biomass following partial grazing defoliation by increasing meristematic tissue activity, increasing photosynthetic capacity, and increasing allocation of carbon and nitrogen. Fully activated mechanisms can produce replacement foliage at 140% of the herbage weight that was removed during grazing (Manske 2000a, b, 2010a, b, 2014a, b). The growth rates of replacement leaves and shoots increase after partial defoliation by grazing. The enhanced activity of meristematic tissue produces larger leaves with greater mass (Langer 1972, Briske and Richards 1995). Developing leaf primordia not fully expanded

at time of defoliation have increased growth rates and tend to grow larger than leaves on undefoliated tillers (Langer 1972). Partial defoliated tillers increase photosynthetic rates of remaining mature leaves and rejuvenated portions of older leaves not completely senescent (Atkinson 1986, Briske and Richards 1995). Changes in cytokinin levels and other signals produced as a result of the increase in the root-shoot ratio rejuvenate the photosynthetic apparatus, inhibit or reduce the rate of senescence, and increase the life span and leaf mass of remaining mature leaves (Briske and Richards 1995). Activation of the compensatory physiological mechanisms after partial defoliation of grass tillers by grazing require alternative sources of abundant carbon and nitrogen (Coyne et al. 1995). Carbon fixed during current photosynthesis in remaining mature leaf and shoot tissue and rejuvenated portions of older leaves is preferentially allocated to areas of active meristematic tissue (Ryle and Powell 1975, Richards and Caldwell 1985, Briske and Richards 1995, Coyne et al. 1995). The quantity of leaf area required to fix adequate quantities of carbon is 67% to 75% of the predefoliated leaf area (Manske 1999, 2011b, 2014c). Very little, if any, of the carbon and nitrogen stored in the root system is remobilized to support compensatory growth (Briske and Richards 1995). The mobilizable nitrogen pools in the shoot tissue are reduced following partial defoliation. This loss in nitrogen from the shoot increases preferential use of the quantities of mineral nitrogen available in the media around the roots (Millard et al. 1990, Ourry et al. 1990). This available soil mineral nitrogen has been converted from soil organic nitrogen by active rhizosphere organisms, absorbed through the roots, and moved to areas of active meristematic tissue.

Vegetative secondary tillers are shoots that develop on lead tillers from growth of axillary buds by the process of tillering (Dahl 1995). Meristematic activity in axillary buds and the subsequent development of vegetative tillers is regulated by auxin, a growth-inhibiting hormone produced in the apical meristem and young developing leaves (Briske and Richards 1995). Tiller growth from axillary buds is inhibited indirectly by auxin interference with the metabolic function of cytokinin, a growth hormone (Briske and Richards 1995). Partial defoliation of young leaf material at vegetative growth stages temporarily reduces the production of the blockage hormone, auxin (Briske and Richards 1994). The abrupt reduction of plant auxin in the lead tiller allows for cytokinin synthesis or utilization in multiple axillary buds, stimulating the development of vegetative secondary tillers (Murphy and Briske 1992, Briske and Richards 1994).

If no defoliation occurs before the flower (anthesis) stage, the lead tiller continues to hormonally inhibit secondary tiller development from axillary buds. Production of the inhibitory hormone, auxin, declines gradually as the lead tiller reaches the flower stage. The natural reduction of auxin in the lead tiller usually permits only one secondary tiller to develop. This developing secondary tiller produces auxin that hormonally suppresses development of additional axillary buds (Briske and Richards 1995). Vegetative tiller growth is the dominant form of reproduction in semiarid and mesic grasslands (Belsky 1992, Chapman and Peat 1972, Briske and Richards 1995, Chapman 1996, Manske 1999) not sexual reproduction and the development of seedlings. Recruitment of new grass plants developed from seedlings is negligible in healthy grassland ecosystems. The frequency of true seedlings is extremely low in functioning grasslands, and establishment of seedlings occurs only during years with favorable moisture and temperature conditions (Wilson and Briske 1979, Briske and Richards 1995), in areas of reduced competition from vegetative tillers, and when resources are readily available to the growing seedling.

Grass plant dominance within a grassland community is related to the plants competitiveness at nutrient and water resource uptake. Crider (1955) found that grass tillers with 50% or more of the aboveground leaf material removed reduce root growth, root respiration, and root nutrient absorption resulting in reduced functionality of these grass plants. Reduction of active root biomass caused diminishment of grass plant health and vigor (Whitman 1974) that resulted in a loss of resource uptake efficiency and a suppression of the competitiveness of grass plants to take up mineral nitrogen, essential elements, and soil water (Li and Wilson 1998, Kochy 1999, Kochy and Wilson 2000, Peltzer and Kochy 2001). The loss of active root length contributed to the reduction of rhizosphere biomass and the decline of ecosystem biogeochemical processes (Coleman et al. 1983, Klein et al. 1988). The nutrient resource uptake competitiveness of healthy grasses is able to suppress the expansion of shrubs and prevent successful establishment of grass, forb, and shrub seedlings into grasslands (Peltzer and Kochy 2001). The grass growth form has competitive advantages of nutrient uptake over the shrub growth form (Kochy and Wilson 2000). Grass aboveground biomass is primarily productive photosynthetic leaves resulting in a high resource uptake efficiency. Grasses are good competitors for belowground nutrient resources and superior competitors for mineral nitrogen because of a high root: shoot ratio

and no woody stems to maintain. Shrubs have a great reduction in resource uptake efficiency because a large portion of the photosynthates produced in the leaves must be used to build and maintain their unproductive woody stems. However, the taller woody stems make shrubs superior competitors for aboveground sunlight resources (Kochy and Wilson 2000). Competition for belowground nutrient resources from healthy grasses reduce the growth rates of shrub rhizomes and cause high mortality rates of young sucker (Li and Wilson 1998).

Shrubs can compete for some of the belowground resources only after the grass plants have been degraded by ineffective management. Following the reduction in grass plant resource uptake competitiveness, the belowground resources no longer consumed by the smaller, less vigorous degraded grasses, are taken up by the shrub plants resulting in proportional increases of biomass production (Kochy and Wilson 2000). With greater nutrient resources, shrub rhizome suckers are able to establish a faster growth rate and a higher survival rate (Li and Wilson 1998). The resulting greater shrub stem density increases the competition for the aboveground resources of light causing strong suppression of the grasses (Kochy and Wilson 2000). Traditionally, the observation of increasing woody shrubs and trees into grasslands would have been explained as a result of fire suppression (Humphrey 1962, Stroddart, Smith, and Box 1975, Wight and Bailey 1982). The invasion of the cool season exotic grasses, Kentucky bluegrass, and smooth brome grass, into much of the northern mixed grass prairie was presumed to be caused by the absence of fire (Kirsch and Kruse 1972). Seedlings of trees, shrubs, weedy forbs, and introduced grasses cannot become established in healthy functioning grassland ecosystems with grasses that have retained full resource uptake competitiveness (Peltzer and Kochy 2001, Manske 2019).

Grasslands of the Northern Plains managed with traditional practices are notorious for their inhibitory deficiency in available soil mineral nitrogen (Goetz et al. 1978) which has been determined to cause the observed low herbage production. Deficiencies in mineral nitrogen limit herbage production more often than water deficiencies in temperate grasslands (Tilman 1990). Total herbage biomass production on grassland ecosystems has been shown to increase with increases in the quantity of available soil mineral nitrogen (Rogler and Lorenz 1957; Whitman 1957, 1963, 1976; Smika et al. 1965; Goetz 1969, 1975; Power and Alessi 1971; Lorenz and Rogler 1972; Taylor

1976; Wight and Black 1979). Greater quantities of available soil mineral nitrogen has been shown to also cause the soil water use efficiency to improve in grassland plants (Smika et al. 1965, Wight and Black 1972, Whitman 1976, 1978). Using a proxy method, Wight and Black (1972) found that precipitation (water) use efficiency of grass plants improved when soil mineral nitrogen was available at threshold quantities of 100 lbs/ac (112 kg/ha) and greater. The inhibitory deficiencies of mineral nitrogen on grasslands that had less than 100 lbs/ac of available soil mineral nitrogen caused the weight of herbage production per inch of precipitation received to be reduced an average of 49.6% below the weight of herbage produced per inch of precipitation on the grassland ecosystem that had greater than 100 lbs/ac of mineral nitrogen and did not have mineral nitrogen deficiencies (Wight and Black 1979). The efficiency of water use in grass plants function at low levels when mineral nitrogen is deficient, and function at high levels when mineral nitrogen is available at threshold quantities of 100 lbs/ac or greater (Manske 2009d). The level of water use efficiency determines the level of herbage biomass productivity on grasslands. Manske (2010a, b) found that the threshold quantity of 100 lbs/ac of available mineral nitrogen was also critical for functionality for two internal grass plant growth mechanisms of the vegetative reproduction by tillering and the compensatory physiological mechanisms. Both of these mechanisms function at high potential levels on grasslands that have 100 lbs/ac or greater available soil mineral nitrogen and do not function or function at extremely low levels on grasslands that have mineral nitrogen deficiencies (Manske 2009c, 2010a, b, c, 2011c).

The indispensable rhizosphere microorganisms are responsible for the performance of the ecosystem biogeochemical processes that determine grassland ecosystem productivity and functionality. Biogeochemical processes transform stored essential elements from organic forms or ionic forms into plant usable mineral forms. Biogeochemical processes capture replacement quantities of lost or removed major essential elements of carbon, hydrogen, nitrogen, and oxygen with assistance from active live plants and transform the replacement essential elements into storage as soil organic matter for later use. Biogeochemical processes decompose complex unusable organic material into compounds and then into reusable major and minor essential elements (McNaughton 1979, 1983; Coleman et al. 1983; Ingham et al. 1985; Mueller and Richards 1986; Richards et al. 1988;

Briske 1991; Murphy and Briske 1992; Briske and Richards 1994, 1995).

The quantity of ecosystem biogeochemical processes conducted is dependent on the quantity of rhizosphere microorganism biomass (Coleman et al. 1983). The greater the microbial biomass, the greater the grassland ecosystem productivity. The greater the productivity, the greater the annual increase in soil organic matter. Increases in the organic matter content of a soil improves the stability of soil aggregates, improves the physical and chemical properties, improves soil air and water infiltration and water holding capacity, improves soil fertility, and increases cation exchange capacity (Schimel, Coleman, and Horton 1985, Six et al. 1998, 2004). Rhizosphere organism biomass and activity are limited by access to simple carbon chain energy (Curl and Truelove 1986) because the microflora trophic levels lack chlorophyll and have low carbon (energy) content.

Partial defoliation by large indispensable grazing graminivores that removes 25% to 33% of the aboveground leaf and shoot weight from grass lead tillers in vegetative phenological growth between the three and a half new leaf stage and the flower stage (Manske 1999) causes large quantities of exudates containing simple carbon compounds to be released through the plant roots into the rhizosphere (Hamilton and Frank 2001). With the increase in availability of energy from simple carbon compounds in the rhizosphere, microorganism activity (Elliot 1978, Anderson et al. 1981, Whipps 1990) and biomass (Gorder, Manske, and Stroh 2004) greatly increase. The elevated biomass and activity of the microfauna trophic levels results in heavy consumption of the low carbon, high nitrogen content microflora trophic levels resulting in ingestion of greater quantities of nitrogen than the microfauna organisms need for a balanced diet based on energy (carbon); the excess nitrogen is excreted as ammonium (NH_4). As a result of the increase in availability of energy from the exudated simple carbon chains, the biomass and activity of rhizosphere organisms greatly increased, transforming greater quantities of organic nitrogen into mineral nitrogen (Coleman et al. 1983, Klein et al. 1988, Burrows and Pflieger 2002, Rillig et al. 2002, Bird et al. 2002, Driver et al. 2005).

The increased available mineral nitrogen is absorbed into grass plant roots and through complex processes, the plant combines the mineral nitrogen with carbon, hydrogen, and oxygen to synthesize different kinds of amino acids which are combined into large organic compounds to produce various

types of proteins, nucleotides, and chlorophyll, resulting in greatly increased herbage biomass production at or near potential biological levels (Manske 1999, 2003). As a result of the great increase in ecosystem net primary productivity, much greater quantities of organic nitrogen are returned annually back to the grassland ecosystem pool of soil organic matter which will raise the ecosystem functionality.

Production of herbage biomass on grassland ecosystems at potential biological levels requires mineral nitrogen to be available at the threshold amount of 100 lbs/ac or greater. The biogeochemical processes of the nitrogen cycle in grassland ecosystems that convert organic nitrogen into mineral nitrogen are a function of the complex symbiotic interactions among rhizosphere organisms, grass plants, and large grazing graminivores. Soil organic matter in grassland ecosystems generally contains about three to eight tons of organic nitrogen per acre. Organic nitrogen is a form of nitrogen not directly usable by grass plants. Organic nitrogen must be transformed into inorganic (mineral) nitrogen in order to be usable by plants. In grassland ecosystems, the transformation of plant usable mineral nitrogen from soil organic nitrogen requires active rhizosphere organisms comprised of several trophic levels of microbes existing in the narrow zone of soil around active roots of perennial grass plants (Harley and Smith 1983, Campbell and Greaves 1990, Caesar-TonThat et al. 2001b).

The nitrogen cycle within grassland soils functions with two major biogeochemical processes. Immobilization is the process of assimilation of mineral nitrogen into organic forms of living organisms. Mineralization is the process of converting organic nitrogen into mineral (inorganic) nitrogen. Mineralization is a complex biogeochemical process conducted by saprotrophic and heterotrophic soil microorganisms that convert immobilized organic nitrogen from soil organic matter detritus into mineral (inorganic) nitrogen (Power 1972). Ammonium salts are the first inorganic nitrogen compounds produced by microbial digestion. Complex proteins and other organic nitrogen compounds are simplified by enzymatic digestion that hydrolyze the peptide bonds and liberate and degrade the amino acids by deamination to produce ammonia (NH_3) and carbon dioxide, or other low molecular weight carbon compounds (Power 1972, Brady 1974). Most of the ammonia released is readily hydrolyzed into stable ammonium (NH_4). The ammonium ions are fairly immobile and some can be oxidized during nitrification producing

nitrite (NO₂) and then nitrate (NO₃) (Brady 1974, Legg 1975, Coyne et al. 1975). The quantity of available nitrate in soil increases when the soil moisture content is abundant (Brady 1974). Mineral nitrogen (NH₄ and NO₃) have several optional biological and chemical pathways and are not available for very long. The quantity of available mineral nitrogen varies with changes in soil microorganism biomass and plant phenological growth and development during the growing season (Whitman 1975) and is the net difference between the total quantity of organic nitrogen mineralized by soil microorganisms and the quantity of mineral nitrogen immobilized into organic forms by plants and soil microbes (Brady 1974, Legg 1975). Maintaining available mineral nitrogen at the threshold quantity of 100 lbs/ac or greater requires a very large biomass of soil microorganisms.

Perpetuation of life on earth requires that the abiotic major and minor essential elements be reused over and over. Recycling of the essential elements is also performed by rhizosphere microorganisms. The essential elements are required for life to exist by ensuring growth and development of organisms and the maintenance of all life functions (table 1). Animals require twenty one elements and plants require seventeen elements. Sixteen of the same essential elements are required by both animals and plants. The four major essential elements: carbon (C), hydrogen (H), nitrogen (N), and oxygen (O) are required in very large amounts by animals and plants. A portion of the major essential elements is lost annually from grassland ecosystems by natural processes and a portion is removed from grassland ecosystems as weight biomass produced by insects and wildlife and as animal growth from essential elements transferred from grass plants to grazing livestock. When greater quantities of major essential elements are lost and removed than the quantities accumulated, the ecosystem degrades (declines). When greater quantities of major essential elements are accumulated than the quantities removed, the ecosystem aggrades (improves). Biologically effective management strategies can replenish the quantity of lost or removed major essential elements by capturing input essential elements from the surrounding environment through ecosystem biogeochemical processes performed by the indispensable rhizosphere microorganisms.

Animals and plants require large amounts of the same five macronutrients: potassium (K), calcium (Ca), phosphorus (P), magnesium (Mg), and sulfur (S). Animals require one additional macronutrient: sodium (Na) and require chlorine (Cl) as a

macronutrient. Warm season plants and cacti use some sodium (Na). Animals and plants require very small amounts of the same seven micronutrients or trace elements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and nickel (Ni). Animals require four additional micronutrients: iodine (I), cobalt (Co), selenium (Se), and chromium (Cr). Plants require one additional micronutrient: boron (B), and require chlorine (Cl) as a micronutrient. A few plants and rhizobia use some cobalt (Co).

The ecosystem source for all of the minor essential elements required by animals and plants is weathered parent material. The elemental content of the parent material greatly influences the quantity of macro - and micronutrients in the soil. The minor essential elements are stored in the soil organic matter as unavailable organic forms or as ions adsorbed by colloidal complexes and are biologically and chemically immobilized, respectively. While in these stable forms, the minor essential elements are not subjected to potential losses through volatilization or leaching movement (Legg 1975, Gibson 2009). The immobilized minor essential elements are made available through the ecosystem biogeochemical cycles performed by rhizosphere microorganisms (McGill and Cole 1981, Cheng and Johnson 1998, Manske 2012b, 2014c). The quantity of available minor essential elements is determined by the recycling rates of soil organic matter decomposition and mineralization that are directly regulated by the biomass of active rhizosphere microorganisms. Without the stimulation from the partial defoliation of grass lead tillers by the indispensable grazing graminivores none of the ecosystem biogeochemical processes and the internal grass plant mechanisms are activated and do not function.

Prescribed burning and mowing grass hay cannot activate the grass plant growth mechanisms or the ecosystem biogeochemical processes because these practices remove too much of the leaf area preventing adequate quantities of carbon energy to be fixed through leaf photosynthesis. Stored carbohydrates are not mobilized for complementary replacement growth following defoliation events (Richards and Caldwell 1985, Briske and Richards 1995).

Repeated prescribed burning can modify the composition of the aboveground vegetation in degraded grasslands which have been invaded by shrubs. The composition of introduced cool season grasses may change, and early succession and weedy forbs, and shrub aerial stems decrease temporarily

after four repeated prescribed burns (Manske 2007a, 2011a). However, the fundamental problems of weak nutrient resource uptake, reduced water use efficiency, nonfunctional compensatory physiological mechanisms, impaired vegetative reproduction by tillering, and diminished ecosystem biogeochemical processes will remain in the degraded grassland ecosystem following repeated burning events. None of the biological, physiological, or asexual mechanisms within grass plants and none of the rhizosphere microbes or biogeochemical processes they perform are activated by fire (Manske 2007a, 2011a). Almost all of the essential elements in the aboveground herbage are volatilized when a grassland is burned, and if the soil is dry, some of the belowground essential elements are also lost (Russelle 1992). When the losses of essential elements are greater than the quantity of captured essential elements, the result is degradation of the grassland (McGill and Cole 1981). Fire does not improve grassland ecosystems biologically, or ecological and fire cannot replace the partial defoliation achieved by grazing graminivores in managing healthy and productive grassland ecosystems (Manske 2018a).

Acknowledgment

I am grateful to Sheri Schneider for assistance in the production of this manuscript and for development of the table.

Table 1. Essential Elements Required by Animals and Plants.

Major Essential Elements required by animals and plants

Carbon (C), Hydrogen (H), Nitrogen (N), Oxygen (O)

Minor Essential Elements

Macronutrients required by animals and plants

Potassium (K), Calcium (Ca), Phosphorus (P), Magnesium (Mg), Sulfur (S)

Macronutrients required by animals

Sodium (Na), Chlorine (Cl)

Micronutrients required by animals and plants

Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu)

Molybdenum (Mo), Nickel (Ni)

Micronutrients required by animals

Iodine (I), Cobalt (Co), Selenium (Se), Chromium (Cr)

Micronutrients required by plants

Boron (B), Chlorine (Cl)

Blue elements required by both animals and plants, Red elements required by animals, Green elements required by plants.

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Attaining Full Functionality of Grassland Ecosystems with the Twice-over Rotation Grazing Management Strategy

Llewellyn L. Manske PhD
Scientist of Rangeland Research
North Dakota State University
Dickinson Research Extension Center
Report DREC 20-1196

Functionality of grassland ecosystems at full biological potential requires recycling adequate quantities of essential elements through the biogeochemical processes performed by the belowground soil microbes in order to replace removed aboveground leaf and stem biomass of grass plants through the primary physiological growth mechanisms, all of which must be activated annually by partial defoliation by grazing graminivores during vegetative growth stages of grass lead tillers.

Grasslands of the Northern Plains managed by traditional practices are low in available mineral nitrogen. This low nitrogen availability has long been known to be responsible for the reduced herbage productivity and below genetic potential calf weight gains per acre. However, intact grasslands have adequate nitrogen, usually at 5 to 6 tons of organic nitrogen per acre, which is not available to plants. Organic nitrogen must be mineralized by soil microorganisms in order for it to be available for plant use in the inorganic form. Unfortunately, traditional and gimmick grazing management practices do not elevate the soil microorganism biomass high enough to support mineralization of organic nitrogen at a level that can yield a supply at the threshold quantity of 100 lbs/ac or greater (Wight and Black 1972, 1979), which will permit the four primary grass plant growth mechanisms and all of the ecosystem biogeochemical processes to function at potential biological levels.

Intact grassland ecosystems that are low in available mineral nitrogen cannot be improved with some quick fix agronomic practice. The application of nitrogen fertilizer to grassland ecosystems does not solve the complex problems related to the cause of low soil mineral nitrogen (Manske 2014). It was found that nitrogen fertilization of native grasslands caused a synchronization of grass tiller growth stage development, resulting in a small increase in herbage biomass which later produced a high rate of leaf senescence and an early season decrease in forage nutritional quality compared to nonfertilized grasslands (Manske 2014). It also caused a short term shift in plant species composition, with an

increase in mid cool season grass (e.g. western wheatgrass) and a decrease in short warm season grasses (e.g. blue grama) (Manske 2009a, 2014). Initially, these changes were considered by most observers to be beneficial (Manske 2009d). However, close examination of the data showed that the costs of the additional herbage weight were excessive (Manske 2009b), and that the long term disruptions of ecosystem biogeochemical processes were detrimental to desirable plant composition (Manske 2010). The reduction of short warm season grasses caused a decrease in total live plant basal cover, thus exposing greater amounts of soil to higher levels of solar radiation and erosion (Goetz et al. 1978). These large areas of open space became ideal invasion sites for undesirable plants, resulting in a long term plant species compositional shift towards a replacement community of domesticated and introduced mid cool season grasses (e.g. Kentucky bluegrass, Smooth brome grass), and in the removal of nearly all the native plant species (Manske 2009c, 2010, 2018a).

Implementation of the strategy to interseed alfalfa into intact semiarid native grassland does not solve the complex problems related to the cause of low soil mineral nitrogen (Manske 2005). The introduction of alfalfa increased demand on the existing low levels of soil mineral nitrogen because almost all of the alfalfa plants' nitrogen requirements had to be taken from the soil. The interseeded alfalfa plants had extremely low levels of nodulation of rhizobium bacteria on the roots and, consequently, almost no nitrogen fixation. The inoculated rhizobium had been consumed by the resident soil microbes before the alfalfa seedlings had grown sufficient root material to permit infection (Manske 2004). The low amounts of mineral nitrogen available in the soil resulted in slower rates of growth and higher rates of mortality for the interseeded alfalfa plants than those for alfalfa plants solid seeded into cropland (Manske 2005). In addition, the high water use of the interseeded alfalfa plants depleted soil water levels within a 5 foot radius from each crown to an average of 35% below ambient soil water levels, causing drought stress conditions in the

adjacent grass plants and, subsequently, further reducing grass herbage production (Manske 2004, 2005). Agronomic strategies implemented on grassland ecosystems slowly stifled grass internal growth mechanisms and ecosystem biogeochemical processes to ineffectiveness (Manske 2018a).

Grassland ecosystems should be managed with sound ecological principles. The ecological method to increase the quantity of available mineral nitrogen to 100 lbs/ac or greater in grassland ecosystems is to increase the biomass of the rhizosphere microorganisms. The rhizosphere is the narrow zone of soil bonded by extracellular adhesive polysaccharides around active roots of perennial grassland plants. The primary biologically active rhizosphere microbes are the endomycorrhizal fungi, ectomycorrhizal fungi, low carbon: high nitrogen bacteria, and normal carbon: nitrogen protozoa. The rhizosphere microbes do not possess chlorophyll nor do they have direct access to sunlight, as a consequence, these microbes are deficient of energy and require an outside source of simple carbon energy. Contrary to common assumptions, there isn't enough short chain carbon energy in recently dead grass material and there isn't enough energy from natural plant leakage to support a large active biomass of soil microbes. The only readily accessible source of large quantities of short chain carbon energy is the surplus fixed carbon energy photosynthesized by grass lead tillers at vegetative phenological growth stages. Grass plants fix a great deal more carbon energy than they use, furthermore, grass plants do not store the surplus fixed energy until during the winter hardening period, which starts in mid August and lasts to hard frost. Surplus carbon energy not programmed for use, is broken down during night respiration. However, grass lead tillers at vegetative growth stages, between the three and a half new leaf stage and the flower (anthesis) stage, can be manipulated to exudate most of the surplus carbon energy into the rhizosphere through the roots following partial removal of 25% to 33% of the aboveground leaf biomass by grazing graminivores. This technique supplies sufficient quantities of short chain carbon energy into the rhizosphere initiating the production of large increases in microbe biomass and activity when 60% to 80% of the grass lead tiller population are partially defoliated by grazing graminivores over a period of 7 to 17 days on each pasture during the 45 day stimulation period from 1 June to 15 July.

Initiation of a twice-over strategy on native grassland that had previously been managed by nongrazing or traditional seasonlong practices will

have a rhizosphere microbe biomass that is low to very low and it will require about three growing seasons to increase the microbe biomass large enough to mineralize 100 lbs/ac of mineral nitrogen. The response from the rhizosphere microbes is not instantaneous and rhizosphere weight changes respond differently to different management treatments (Manske 2018b).

Management of grassland ecosystems without large grazing graminivores is not sustainable. Forty-five years of research have been devoted to the development of a biologically effective grazing management strategy that can improve and maintain grassland ecosystems at their potential biological levels.

The biologically effective twice-over rotation strategy was designed to coordinate partial defoliation events with grass phenological growth stages, to meet the nutrient requirements of the grazing graminivores, the biological requirements of the grass plants and the rhizosphere microorganisms, to enhance the ecosystem biogeochemical processes, and to activate the internal grass plant growth mechanisms in order for grassland ecosystems to function at the greatest achievable levels.

The twice-over rotation grazing management strategy uses three to six native grassland pastures. Each pasture is grazed for two periods per growing season. The number of grazing periods is determined by the number of sets of tillers: one set of lead tillers and one set of vegetative secondary tillers per growing season. The first grazing period is 45 days long, ideally, from 1 June to 15 July, with each pasture grazed for 7 to 17 days (never less or more). The number of days of the first grazing period on each pasture is the same percentage of 45 days as the percentage of the total season's grazeable forage contributed by each pasture to the complete system. The forage is measured as animal unit months (AUM's). The average grazing season month is 30.5 days long (Manske 2012a). The number of days grazed are not counted by calendar dates but by the number of 24-hr periods grazed from the date and time the livestock are turned out to pasture. The second grazing period is 90 days long, ideally from 15 July to 14 October, each pasture is grazed for twice the number of days as in the first period. The length of the total grazing period is best at 135 days; 45 days during the first period plus 90 days during the second period.

There is some flexibility in the grazing period dates. The starting date has a variance of plus or minus 3 days with a range of start dates from 29 May to 4 June. This gives an extreme early option to start on 29 May with the first period to 12 July and with the second period to 11 October. The extreme late alternative option can start on 4 June with the first period to 18 July and with the second period to 17 October. There is also the option to add a total of 2 days to the total length of the grazing period. These 2 days can be used when a scheduled rotation date occurs on an inconvenient date by adding one day to each of two rotation dates. The limit of additional days is two per year resulting in a total length of 137 days. If inconvenient rotation dates occur during 3 or more times, an equal number of days greater than two must be subtracted from the grazing season, so total number of days grazed per year does not exceed 137 days. If the start date is later than 4 June, the scheduled rotation dates must remain as if the start date were on 4 June, in order to maintain the coordinated match of the partial defoliation events with the grass phenological growth stages. The total number of days grazed will be 135 days minus the number of days from 4 June to the actual start date. However, it is best to start on 1 June each year.

During the first period, partial defoliation that removes 25% to 33% of the leaf biomass from grass lead tillers between the 3.5 new leaf stage and the flower stage increases the rhizosphere microbe biomass and activity, enhances the ecosystem biogeochemical processes, and activates the internal grass plant growth mechanisms. Manipulation of these processes and mechanisms does not occur at any other time during a growing season. During the second grazing period, the lead tillers are maturing and declining in nutritional quality and defoliation by grazing is only moderately beneficial to grass development. Adequate forage nutritional quality during the second period depends on the activation of sufficient quantities of vegetative secondary tillers from axillary buds during the first period. Livestock are removed from intact grassland pastures in mid October, towards the end of the perennial grass growing season, in order to allow the carryover tillers to store the carbohydrates and nutrients which will maintain plant mechanisms over the winter. Most of the upright vegetative tillers on grassland ecosystems during the autumn will be carryover tillers which will resume growth as lead tillers during the next growing season. Almost all grass tillers live for two growing seasons, the first season as vegetative secondary tillers and the second season as lead tillers. Grazing carryover tillers after mid October causes the termination of a large proportion of the population,

resulting in greatly reduced herbage biomass production in subsequent growing seasons. The pasture grazed first in the rotation sequence is the last pasture grazed during the previous year. The last pasture grazed has the greatest live herbage weight on 1 June of the following season (Manske 2018a).

Stocking rates are based on peak herbage biomass on seasonlong grazing practices. The starting stocking rate on the “new” twice-over grazing practice is usually 80% to 100% of the seasonlong stocking rate (Manske 2012b). It usually requires three grazing seasons with the twice-over strategy stocked at 100% to increase the rhizosphere microbe biomass to be great enough to mineralize 100 lbs/ac of mineral nitrogen (nitrate NO_3 and ammonium NH_4). After the increased rhizosphere microbe biomass can mineralize 100 lbs/ac of mineral nitrogen, the stocking rate can be increased at 10% per year until the system is stocked at 140% of the seasonlong stocking rate. This has been the maximum biological potential reached on North American grasslands from the twice-over rotation strategy.

Once a rotation date scheduled has been determined, do not change that schedule greater than one day for any worldly reason. If you do not like your neighbors bull, build a fence that the bull cannot jump. If you have water sources that sometimes go dry, put in a water tank system on a pipeline. Fix the problems that develop with solutions that do not change the rotation schedule.

Implementation of a twice-over rotation strategy will activate functionality of the four primary grass physiological growth mechanisms at much higher rates during the summer grazing period of 1 June to 14 October with the availability of 100 lbs/ac mineral nitrogen than the lower grass growth rates on traditional seasonlong practices with inadequate quantities of mineral nitrogen. On the twice-over rotation strategy, the greater than 100 lbs/ac mineral nitrogen result in higher functioning rates of the grass growth mechanisms causing cool season grass lead tiller biomass to be 25.5% greater during the July peak and causing a secondary vegetative tiller biomass to be 50.7% greater during the second peak in September, and causing warm season grass lead tiller biomass to be 29.9% greater during the peak in September and October, which causes total native grass herbage biomass to be 31.2% greater than those on the seasonlong treatment during the growing season. The increased grass biomass and improved nutrient content result in greater stocking rates, with calf weight gain per acre to be 23.0% greater, and

cow weight gain per acre to be 46.9% greater than the productivity on traditional seasonlong grazing practices (Manske 2018c).

Acknowledgment

I am grateful to Sheri Schneider for assistance in production of this manuscript.

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