MONTANA STATE UNIVERSITY

Habitat preferences of sharp-tailed grouse broods on the Charles M. Russell National Wildlife Refuge
by Kim Richard Bousquet

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University
© Copyright by Kim Richard Bousquet (1996)

Abstract:
Nesting and brood-rearing ecology of sharp-tailed grouse (Tympanuchus phasianellus jamesi) were studied on the western end of the Charles M. Russell National Wildlife Refuge in northcentral Montana in 1994 and 1995. Annual censusing of sharp-tailed grouse on traditional dancing grounds revealed an 80% increase in the number of dancing males between 1994-95. I radiotagged 42 sharp-tailed grouse females and relocated them every other day from nest initiation until early September in 1994 and 1995. I located 36 nests, 75% of which were initiated within the first week of May in both years. Mean clutch size was 12.2 eggs for both years, and the peak of hatching occurred during the second and third weeks of June. Most nests (64%) were located in big sagebrush (Artemesia tridentata) with an average canopy height of 42 cm and screening cover height of 21 cm. Nest sites were characterized as having greater screening-cover height than random sites. Nest success significantly differed between years (P = 0.02) and was 92% in 1994 and 53% in 1995. Apparently, cold, wet weather and canid predation on nesting females were the main factors leading to the decrease in nest success in 1995. Hen survival during the 1994-95 nesting seasons averaged 75%. Fifty-seven percent of all female deaths were due to coyotes (Cams latrans). In addition, 2 females appeared to have died from rattlesnake (CrotaIus viridis) bites during the nesting period. Hen survival after nesting was 100% (n = 29) in 1994-95. Data were obtained for 21 broods during 1994-95. Average brood size at hatching was 11.3 chicks (n = 21) over both years. Ten of 21 (47%) broods and 60 of 236 (25%) chicks survived to 56 days in 1994-95. Chick survival was 44% in 1994 and 9% in 1995. Brood daily habitat-use patterns were characterized by broods using grass/shrub cover during the early morning and evening hours for feeding, and shrub/grass cover for dusting and resting during mid-day. Young broods used areas with new grass and yellow sweetclover (Melilotus officinalis) (areas with high insect densities). Older broods selected areas with greater densities of big sagebrush and Rocky Mountain juniper (Juniperus scopulorum). Univariate analyses indicated that in both years brood sites contained more shrubs and had greater vegetative cover density than random sites. Over both years, 81% of nests and 52% of brood locations were in areas frequented by domestic livestock. Management for dense cover and dense shrubs, should benefit sharp-tailed grouse productivity. Results of this study suggest that vegetation should be managed to maintain a screening cover height of at least 20 cm and canopy heights > 42 cm for nesting sharp-tailed grouse. If current livestock grazing removes vegetative cover below the 20 cm screening height, management actions should be taken in the form of reducing cattle stocking rates or setting aside some of the more productive grouse habitat areas.

HABITAT PREFERENCES OF SHARP-TAILED GROUSE BROODS ON THE CHARLES M. RUSSELL NATIONAL WILDLIFE REFUGE

by

Kim Richard Bousquet

A thesis submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

May 1996

N378
B668

APPROVAL

of a thesis submitted by

Kim Richard Bousquet

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Dr. Jay J. Rotella _____ (Signature) 4/19/96 Date

Approved for the Department of Biology

Dr. Ernest R. Vyse _____ (Signature) 4/19/96 Date

Approved for the College of Graduate Studies

Dr. Robert L. Brown _____ (Signature) 5/10/96 Date

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University-Bozeman, I agree that the Library shall make it available to borrowers under rules of the Library.

If I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U. S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted by the copyright holder.

Signature Kim Bousquet

Date 4/19/96

ACKNOWLEDGMENTS

I would like to express my appreciation to the following, among others, for their contribution to this study. Dr. Jay J. Rotella, Montana State University, for technical supervision, project planning, and advice during the preparation of this manuscript. I thank Dr. Robert L. Eng, Dr. Lynn Irby, and Dr. Robert White from Montana State University, for their technical support and critical review of the manuscript, and Dr. Richard Mackie, Montana State University, for his logistical support during this study. I wish to express my gratitude to the U. S. Fish and Wildlife Service and the staff at Charles M. Russell National Wildlife Refuge for assistance and logistical support throughout this study, and special thanks to Randy Matchett for his endless technical and logistical support, and project planning. I thank Kevin Pudruzny for testing the telemetry system used throughout this study, and my sincere appreciation to Caleb Balas, mother Edith Bousquet, daughter Jessica, and Shane Floyd for their efforts trapping and collecting data for this study. I would like to express my heart felt appreciation to my wife Kelly for her undying support during this study.

TABLE OF CONTENTS

Page

LIST OF TABLES vii

LIST OF FIGURES ix

ABSTRACT x

INTRODUCTION 1

DESCRIPTION OF STUDY AREA 4

METHODS 8

Productivity 8
Censusing, Capture and Marking 8
Nest Data 8
Brood Data 10
Survival Data 10
Habitat Selection 11
Nest Habitat 11
Brood Habitat 12
Movements and Home Range 13

Data Analysis 13

RESULTS 16

Productivity 16
Censusing, Capture and Marking 16
Nest Data 18
Brood Data 21
Habitat Selection 21
Nest Habitat 21
Univariate Analysis 24
Multivariate Analysis 24

TABLE OF CONTENTS--Continued

Page

Habitat Selection (continued)
Brood Habitat 28
Univariate Analysis 30
Multivariate Analysis 33
Movements and Home Range 33

DISCUSSION 36
Productivity 36
Nest Data 36
Brood Data 38
Habitat Selection 39
Nest Data 39
Brood Data 40
Movements and Home Range 42

MANAGEMENT IMPLICATIONS 44

LITERATURE CITED 46

APPENDIX 53

LIST OF TABLES

Table | Page

1. Annual sharp-tailed grouse trapping results at Charles M. Russell NWR, Montana, 1994-1995 17

2. Annual sharp-tailed grouse nesting data at Charles M. Russell NWR, Montana, 1994-1995 20

3. Survival data for sharp-tailed grouse broods and chicks at Charles M. Russell NWR, Montana, 1994-1995 22

4. Results of univariate analyses of habitat variables comparing sharp-tailed grouse nest-site habitat to random habitat sites at the Charles M. Russell NWR, Montana 1994-1995 25

5. Results of univariate analyses of habitat variables comparing sharp-tailed grouse successful nests to unsuccessful nests at the Charles M. Russell NWR, Montana, 1994-1995 27

6. Results of stepwise logistic regression of habitat variables related to sharp-tailed grouse nest-site selection at the Charles M. Russell NWR, Montana, 1994-1995 29

7. Summary of brood vegetative plots at the Charles M. Russell NWR, Montana, 1994-1995 30

8. Results of univariate analyses of habitat variables comparing sharp-tailed grouse brood-site habitat to random habitat sites at the Charles M. Russell NWR, Montana, 1994-1995 31

9. Results of stepwise logistic regression of habitat variables related to sharp-tailed grouse brood-site selection at the Charles M. Russell NWR, Montana, 1994-1995 34

10. Data summary of sharp-tailed grouse females captured in Nichols Coulee Habitat Unit at the Charles M. Russell NWR, Montana, 1994-1995 54

11. Summary of physical characteristics of sharp-tailed grouse captured in Nichols Coulee Habitat Unit at the Charles M. Russell NWR, Montana, 1994-1995 57

LIST OF TABLES--Continued

Table | Page

12. Plant nomenclature by cover type in Nichols Coulee Habitat Unit at the Charles M. Russell NWR, Montana, 1994-1995..... 58

LIST OF FIGURES

Figure Page

1. Aspect of sharp-tailed grouse nest-sites at the Charles M. Russell NWR, Montana, 1994-1995 23

ABSTRACT

Nesting and brood-rearing ecology of sharp-tailed grouse (Tympanuchus phasianellus jamesi) were studied on the western end of the Charles M. Russell National Wildlife Refuge in northcentral Montana in 1994 and 1995. Annual censusing of sharp-tailed grouse on traditional dancing grounds revealed an 80% increase in the number of dancing males between 1994-95. I radiotagged 42 sharp-tailed grouse females and relocated them every other day from nest initiation until early September in 1994 and 1995. I located 36 nests, 75% of which were initiated within the first week of May in both years. Mean clutch size was 12.2 eggs for both years, and the peak of hatching occurred during the second and third weeks of June. Most nests (64%) were located in big sagebrush (Artemesia tridentata) with an average canopy height of 42 cm and screening cover height of 21 cm. Nest sites were characterized as having greater screening-cover height than random sites. Nest success significantly differed between years ($P = 0.02$) and was 92% in 1994 and 53% in 1995. Apparently, cold, wet weather and canid predation on nesting females were the main factors leading to the decrease in nest success in 1995. Hen survival during the 1994-95 nesting seasons averaged 75%. Fifty-seven percent of all female deaths were due to coyotes (Canis latrans). In addition, 2 females appeared to have died from rattlesnake (Crotalus viridis) bites during the nesting period. Hen survival after nesting was 100% ($n = 29$) in 1994-95. Data were obtained for 21 broods during 1994-95. Average brood size at hatching was 11.3 chicks ($n = 21$) over both years. Ten of 21 (47%) broods and 60 of 236 (25%) chicks survived to 56 days in 1994-95. Chick survival was 44% in 1994 and 9% in 1995. Brood daily habitat-use patterns were characterized by broods using grass/shrub cover during the early morning and evening hours for feeding, and shrub/grass cover for dusting and resting during mid-day. Young broods used areas with new grass and yellow sweetclover (Melilotus officinalis) (areas with high insect densities). Older broods selected areas with greater densities of big sagebrush and Rocky Mountain juniper (Juniperus scopulorum). Univariate analyses indicated that in both years brood sites contained more shrubs and had greater vegetative cover density than random sites. Over both years, 81% of nests and 52% of brood locations were in areas frequented by domestic livestock. Management for dense cover and dense shrubs, should benefit sharp-tailed grouse productivity. Results of this study suggest that vegetation should be managed to maintain a screening cover height of at least 20 cm and canopy heights $\geq$ 42 cm for nesting sharp-tailed grouse. If current livestock grazing removes vegetative cover below the 20 cm screening height, management actions should be taken in the form of reducing cattle stocking rates or setting aside some of the more productive grouse habitat areas.

INTRODUCTION

Plains sharp-tailed grouse (Tympanuchus phasianellus jamesi), 1 of 6 subspecies of sharp-tailed grouse, inhabit tallgrass and mixed-grass prairies, sagebrush plains, and brushy mountain subclimax communities throughout their range (Aldrich 1963). Plains sharp-tailed grouse originally ranged from northcentral Alberta, throughout the northwest and central United States, and as far south as Kansas and northern New Mexico (Johnsgard 1983). Since the 1930's, their range has contracted northward (Aldrich 1963, Johnsgard 1975). Populations in New Mexico and Kansas have been extirpated, and only remnant populations remain in Colorado (Johnsgard 1983). In Montana, fall harvest of sharp-tailed grouse has declined from 75,000 birds in 1987 to 35,000 birds in 1993 (number of upland game bird hunters remained relatively constant at 35,000 during the same time frame) (MFGC 1993). Reductions in sharp-tailed grouse abundance and distribution have been attributed to habitat losses by modern agricultural practices, domestic livestock grazing, fire suppression, and increases in predator populations (Aldous 1943, Aldrich 1963:540, Kirsch et al. 1973, Sisson 1976, Miller and Graul 1980, Bergerud 1988b, Hoag and Braun 1990). Thus, we need to more effectively manage sharp-tailed grouse populations and their remaining habitat.

The most critical aspect of sharp-tailed grouse ecology is the reproductive season. A key factor driving productivity is nest success. Several studies have reported nest success for sharp-tailed grouse in grassland habitats (Christenson 1970, Sisson 1976, Kohn 1976) and shrub habitats, e. g., snowberry (Symphorcarpus sp.) (Aldous 1943, Nielsen 1978) and antelope bitterbrush

(Purshia tridentata) (Meints 1991). However, reports of nest success in sagebrush (Artemesia sp.) habitats are limited (Marks and Marks 1987a, Gunderson 1990). Although several studies have reported estimates of nest success, estimates of hen success are few (Meints 1991).

Another factor driving productivity is chick production. Several studies have estimated brood sizes (Symington and Harper 1957, Marks and Marks 1987a, Gunderson 1990, Meints 1991) and others have reported factors influencing chick mortality (Artman 1970, Christenson 1970, Nielsen 1978, Kobriger 1978). Although, most past studies have focused on chick mortality, Bergerud (1988b) suggested that most estimates may have been biased low, i. e., chick survival was overestimated because of the failure to account for the losses of entire broods. Managers need to have more accurate chick survival estimates in order to better assess sharp-tailed grouse productivity.

Researchers have also attempted to define habitat relationships of sharp-tailed grouse broods since the early 1970's, but most have suffered from small sample sizes (Christenson 1970, Gunderson 1990, Klott and Lindzey 1990, Meints 1991). Also, most of the research conducted on sharp-tailed grouse broods in the last 20 years has focused on the endangered Columbian subspecies (T. p. columbianus) (Giesen 1983, Oedekoven 1985, Marks and Marks 1987a, Klott and Lindzey 1990, Meints 1991, Cope 1992) which inhabit mountain shrub communities. In addition, there was high variability in the type of habitats reportedly used by sharp-tailed grouse broods. Hamerstrom (1963) in Wisconsin, determined grassland with shrubs to be the most important cover for sharp-tailed grouse broods. Christenson (1970) found that broods selected for brushy or wooded draws in North Dakota. Klott and Lindzey (1990) found

that broods most often occurred in sagebrush-snowberry in Wyoming. Broods in Idaho were found in big or low sagebrush, in or adjacent to aspen (Populus sp.) groves, and within antelope bitterbrush (Marks and Marks 1987a, Meints 1991). Gunderson (1990) found most brood sites in juniper cover in Montana. Given, the variability in results, data are needed for other areas to allow better understanding of geographic patterns of habitat use.

Some researchers have indicated that vegetative cover density and plant height may be more important to broods than species composition (Kobriger 1980, Oedekoven 1985, Marks and Marks 1987a, Meints 1991). However, studies corroborating or refuting these results are lacking.

In spite of the knowledge gained by past studies, managers still do not have adequate information on nest and hen success, chick production and survival, and brood habitat-use relationships. Understanding brood-habitat needs is necessary for effective sharp-tailed grouse management. Further data are needed to help identify sharp-tailed grouse management goals. Therefore, I designed this study with the following objectives: (1) estimate productivity of sharp-tailed grouse by estimating clutch size, nest success, brood survival, and survival of hens during the breeding season; and (2) estimate habitat use and selection by breeding sharp-tailed grouse by estimating characteristics of sites used for nesting and brood-rearing as well as characteristics of random sites.

STUDY AREA

My study was conducted in the western portion of the Charles M. Russell National Wildlife Refuge (CMRNWR) on the 20,655 ha Nichols Coulee Habitat Unit (NCHU). The CMRNWR of central Montana was primarily established for the benefit of sharp-tailed grouse in 1936. CMRNWR consisted of 445,000 hectares (1.1 million acres) including Fort Peck Reservoir. CMRNWR was located in 5 counties in northcentral Montana (Fergus, Petroleum, Garfield, Valley, and Phillips). NCHU was located in south Phillips County, Montana (47°36'-47°42'N, 108°13'-108°22'W) and was bordered to the north by Bureau of Land Management lands and to the south by the Missouri River. The area consisted of upland sagebrush plains and rolling grasslands dominated by western wheatgrass (Agropyron smithii), green needlegrass (Stipa viridula), and blue grama (Bouteloua gracilis). Yellow sweet clover, American vetch (Vicia americana), western yarrow (Achillea lanulosa), and curlycup gumweed (Grindelia squarrosa) were common forbs. Dominant shrubs included big sagebrush, Rocky Mountain juniper, and fringed sagewort (A. frigida). Uplands were dissected by a network of shallow coulees that diverged into the Missouri River Breaks, which were dominated by ponderosa pine, Rocky Mountain juniper, prairie rose (Rosa arkansana), and western snowberry (Symphorcarpus occidentalis). Dominant grasses on upland sites included bluebunch wheatgrass (Agropyron spicatum), western wheatgrass, and green needlegrass. Common forbs included American vetch, rubberweed (Hymenoxys richardsoni), western yarrow, and common salsify (Tragopogon dubius). Lowland areas were dominated by silver sagebrush (A. cana) and black greasewood (Sarcobatus

vermiculatus) with rubber rabbitbrush (Chrysothamnus nauseosus) also present. Riparian zones within the NCHU contained sparse stands of cottonwood trees (Populus deltoides), willows (Salix spp.), and sedges (Carex spp.).

During this study, I defined 8 cover types in NCHU based on dominant vegetation, canopy coverage, and topographical location. I used a series of 10 transects, each 67.5 m long (3 consecutive 0.04-ha plots with 22.5-m diameters), to measure representative stands of each type. Transects were systematically placed a minimum of 15 m inside each stand type to prevent edge effects. Plant nomenclature followed Hitchcock and Cronquist (1973), Dorn (1984), and USDA (1988). The 8 cover types were grouped into 3 community types (grassland, shrub, and conifer). Grassland covered most of the upland plains in NCHU and extended down finger ridges that diverged into the Missouri River breaks (from here called breaks).

I delineated 4 grassland types: grass, grass/shrub, grass/forb, and forb/grass. The grass cover type (53% grass, 2% shrubs, and 4% forbs) was the least common grassland and occurred in areas recently disturbed by fire on flat to gentle sloping plains, around stock ponds, and drainage bottoms. The grass/shrub grassland type was the most common cover type (40% grass, 13% shrubs, and 9% forbs) and encompassed most of the upland plains, surrounded most prairiedog (Cynomys ludovicianus) towns, and formed a transition zone between the breaks and the river bottom. The grass/forb grassland cover type (36% grass, 18% forbs, and 13% shrubs) existed in scattered patches on gentle sloping (<10% slope) coulees in the uplands to gentle sloping (< 10% slope) areas within the breaks. The forb/grass grassland cover type (40% forbs, 18% grass, and 9% shrubs) (yellow sweet clover: 1994, pinnate tansy mustard: 1995)

formed a tall blanket leaving only taller shrubs and grasses showing. This cover type reverted to a cover type with dense, residual forb stems in the spring. The forb/grass type occurred on upland finger ridges that branched off into the breaks, on gentle slopes in the breaks, and in the transition zone between the river bottom and breaks.

I delineated 3 shrub cover types: shrub/grass, fringed sagewort (a half-shrub here referred to as a shrub), and juniper. The shrub/grass shrub type (31 % shrubs, 18% grass, and 4% forbs) occurred on the uplands in the bottom of shallow, finger coulees, on and along ridge tops, on flat broad undisturbed plains, and on the gentle slopes along the steeper drainages within the breaks. This type surrounded and feathered into the conifer community. The fringed-sagewort shrub type (75.5% bareground, 22% shrub cover, 2% forb, and 0.5% grass cover) occurred on 14 prairiedog towns on the uplands. The juniper-shrub type (71% shrubs, 4% grass, and 2% forbs) typically occurred in small linear patches, and was surrounded by shrub/grass or grass/shrub cover types and also bordered the conifer community. The conifer community consisted of the ponderosa-pine type, which outlined the area's drainage system and inhabited the gently sloping terrain on ridge tops and steeper slopes within the breaks. (See Table 12 in Appendix A for full description of vegetation in each cover type).

Soils were primarily clay (Veseth and Montagne 1980). Erosion and runoff were high due to soil impermeability. Over 64 km of tertiary roads encircled the study area. The climate was characterized by low precipitation (generally < 31 cm) and temperature extremes ranged from 38 ^{o}C in summer to -

34 ^{o}C during winter, with most precipitation falling from April to June in sudden, sporadic thunderstorms typically developed in the afternoon and evening hours.

Two pastures in NCHU were leased for livestock grazing (Seven mile and C. K.) (4,064 AUM's allotted). Stocking rates were approximately 5.0 ha / AUM in both pastures, and grazing occurred from 1 June to early September.

METHODS

Productivity

Censusing, Capture and Marking

Sharp-tailed grouse censusing took place each year from mid-April through early May on the Refuge. Listening surveys were conducted by refuge personnel from 0.5 hours before sunrise until 2 hours after sunrise to monitor dancing grounds, count the number of males present on leks, and monitor the distribution and relative abundance of sharp-tailed grouse on the Refuge. These data were used to determine peak of the breeding season and to help determine on which dancing grounds to capture sharp-tailed grouse.

I trapped sharp-tailed grouse throughout April and early May on 4 sharp-tailed grouse dancing grounds using W-style walk-in traps (Toepfer et al. 1988a). Dancing grounds were selected based on accessibility, number of birds present, and juxtaposition of dancing grounds. Captured birds were weighed, classified as yearlings (<1 year of age) or adults (>1 year of age) based on outer wear of primaries (Ammann 1944), and sexed by examining crown feathers and central rectrices (Henderson et al. 1967). Each grouse was uniquely marked with 3 color-coded, plastic, leg bands and 1 numbered, aluminum leg band. Captured females were fitted with necklace-style radio transmitters that weighed 15.0 gms, had a 16-cm antenna, 12-hour mortality sensor, and 18-month battery.

Nest Data

During the nesting season, I attempted to locate each female daily until her nest site had been identified. I used an elevated, truck-mounted, null-

antenna system (5-element yagi antenna) (Rotella and Ratti 1991) and a 3-element hand-held yagi antenna (Mech 1983) to locate females. When females could not be found via ground tracking, I used a Cessna 172 airplane with a two-element yagi mounted on each strut to relocate females. If the mortality sensor of a hen's radio was activated, I assumed she was dead, located her immediately, and assessed the cause of death.

I assumed that a female was nesting if she was estimated to be in the same location for ≥2 days. On the third day that a female was estimated to be in the same location, I homed to within 30 m of the female using a hand-held receiving system to estimate the possible nest location. I waited another 10 days before flushing the female and locating her nest. This procedure provided general nest-site information for nests that were destroyed or abandoned during egg laying or early incubation and reduced researcher-caused abandonment of nests.

I recorded the following variables for each nest: nest location, clutch size, stage of incubation, estimated nest-initiation date, and expected hatch date. Stage of incubation was estimated by floating eggs (Westerskov 1950). Nest-initiation dates were estimated by backdating using clutch size and incubation stage. Expected hatch dates were estimated by calculating the remaining number of days needed to complete the average 24-day incubation period. A nest was considered successful if ≥1 egg hatched. The number of chicks hatched from each nest was determined by examining nest bowls for membranes and unhatched eggs within 24 hours after hatching (Rearden 1951).

Brood Data

After a brood hatched, I used telemetry to estimate the dispersal pattern from the nest. I located each brood at least once every 2 days when possible using alternating location times (0500-1000-hr, 1000-1700-hr, and 1700-2200-hr) to ensure samples were acquired throughout the day. I used 2 types of location estimates: (1) visual locations or (2) coordinates estimated by approaching to within 20 m of a brood (ascertained from signal strength and by circling a brood). The second method did not involve flushing the hen or brood and was used most frequently to minimize brood disturbance. Each female with a brood was radio-tracked until she abandoned or lost her brood, left the study area, died, or her brood reached the age of 56 days. After 56 days post-hatching, juveniles were considered to be recruited into the fall sharp-tailed grouse population because by that age their mobility and patterns of cover type use reportedly parallel those of adults (Christenson 1970, Gunderson 1990). I classified broods by age with young broods being <4 weeks old and old broods 4-8 weeks old.

Survival Data

Survival data were obtained for radio-marked hens and their nests, broods, and chicks. Hen survival was the proportion of instrumented females alive at the end of the reproductive season. Nest success was the proportion of nests that had ≥1 egg hatch. Hen success was the proportion of hens that had a successful nest. A brood was considered successful if ≥1 chick survived to 56 days of age. I attempted to count the number of chicks in each female's brood every 2 weeks. If a brood was not observed within 2 weeks, the hen was flushed

to obtain brood and chick survival data. Hens suspected of having lost broods were intensively radio tracked for several days. I concluded that a hen lost her brood if no chicks were observed during the intensive tracking period, if the hen made a sudden uncharacteristic move to a distant area and no chicks were observed, or if she was repeatedly seen with other adult grouse. To ensure that all broods were accounted for, I made final brood checks on hens that were suspected of having lost their broods during the field season. During a final brood check, I homed in on each female by circling with a hand-held receiving system until the female flushed. If no chicks were immediately observed, I systematically searched back and forth within a 25 m radius around the location where the female flushed.

Chick survival data were obtained by locating females with broods 3 times each week throughout each field season. Occasionally chicks could be observed while feeding or when they moved from a feeding area to resting cover. Thus, I was able to determine brood presence and visually estimate brood size. A final chick count was made when each brood was 56 days old to estimate chick survival.

Habitat Selection

Nest Habitat

I obtained habitat data for nest sites, associated random sites (NAR), and study area random sites (NSAR). I measured vegetation in all plot types $\leq$3 days after either eggs hatched or would have hatched if the nest had not been abandoned or depredated. Measurements of random habitat plots were concurrent with nest plot measurements to minimize phenological differences

due to timing differences in measurements. I used circular plots 22.5 m in diameter (0.04 ha). Nest plots were centered on nest sites. Two NAR plots were selected within 100 meters of each nest at random distances and directions from the nest. NSAR plots were placed along the road system throughout the study area using random assignment of road number, distance from road (0-0.8 km), and direction from the road.

I measured the following habitat variables at all plots: dominant and subdominant vegetation type; cover type; cover density; canopy cover; canopy height of dominant shrubs, forbs, and grasses; amount of shrubs, forbs, grasses, and bare ground; species composition; species diversity for each vegetation class; aspect; and height-density pole (HDP) readings (Robel et al. 1970). A vegetation profile board (Nudds 1977) was used to estimate cover density in each of 3 height categories (<0.3, 0.3-0.6, and 0.6-0.9 m). The profile board was placed at the plot center and read from 7.5 m away in each cardinal direction. Canopy coverage of shrubs, forbs, grasses, and bare ground was estimated (in meters) along 2 perpendicular, but randomly oriented, transects, each 22.5 m long. Within each plot, I evaluated species composition and recorded the average height of each species.

Brood Habitat

I also obtained habitat data for sites used by broods, associated random plots (BAR), and study-area random plots (BSAR). I collected data at brood plots and BAR plots ≤7 days after brood sites were located. BSAR site data were collected throughout the brood rearing period. I used the same plot sizes, habitat variables, and data collection methods as for nest plots.

Movements and Home Range Data

I estimated distances moved by females and their broods using locations where females were trapped and subsequently found during the nesting and brood-rearing season. I calculated the distance from each dancing ground used by a female to her nest site(s). Brood locations were used to calculate brood home ranges using program CALHOME and the adaptive kernel and minimum convex polygon methods (Kie et al. 1994).

Data Analysis

I used chi-square analysis (Yate's corrected) to compare nest-initiation dates and nest success between adult and yearling females. I also used chi-square analysis to test for differences in annual nest-survival estimates. I used t-tests to compare clutch sizes of adult and yearling females.

I used chi-square analysis (Yate's corrected) to compare annual brood survival rates. Because fates of broodmates may not have been independent, I calculated chick survival for each brood and used these estimates to estimate annual chick survival. Thus, sample sizes for analyses of chick survival were the numbers of broods not the numbers of chicks. I transformed (arcsin-sqrt) chick survival data and then used t-tests to compare annual chick survival.

I used chi-square analysis to compare used and available vegetative cover types for nesting females. I used the methods of Marcum and Loftsgaarden (1980) to test whether brood-habitat use was related to brood age, time of day, or time of year. When analyzing time-of-day influences, I combined data from morning (0500-1000 hr) and evening (1700-2200 hr) and compared

them with data from mid-day (1000-1700 hr). I compared data from mid-June to mid-July with data from mid-July to mid-August when testing for differences by time of year.

I used univariate and multivariate analyses to test for differences in microhabitats used for nesting and brood rearing. ANOVA was used to compare each habitat variable among: (1) nest, NAR, and NSAR plots and (2) brood, BAR, and BSAR plots. When results of ANOVA were significant, I used protected least-significant-difference tests (Steel and Torrie 1980:176) to indicate which plot types were different. Cover density readings were transformed (arcsin-sqrt) prior to conducting ANOVA to alleviate bias associated with analyzing proportion data.

I also conducted multivariate analysis of habitat at used and random plots using logistic regression (Hosmer and Lemeshow 1989). An explanatory variable was a candidate in the logistic-regression model if univariate analysis of site type versus that variable indicated that site type was different for different levels of the explanatory variable ($P < 0.25$, Hosmer and Lemeshow 1989:82-87). All candidate explanatory variables were entered into stepwise logistic regression, and the best model was chosen based on likelihood-ratio values for each model (Hosmer and Lemeshow 1989:106-112). The significance level for entry into the model was $P = 0.05$. Fit of the chosen model was evaluated by dividing the model chi-square by -2 times the log-likelihood of the null model, which can be interpreted as the proportion of the log-likelihood explained by the model being tested (MathSoft, Inc. 1994).

When interpreting the significance of statistical tests, I used 0.05 as a guideline. However, in univariate tests comparing use sites to random sites, I

conducted multiple tests of the hypothesis of no difference between use sites and random sites, i.e., I compared 10 habitat variables between use sites and random sites. Therefore, I used Bonferroni-corrected significance levels when evaluating the significance of the results of multiple tests of the same hypothesis (0.005 = α/k, where k = the number of habitat variables compared). Multivariate analyses were conducted using PROC LOGISTIC (SAS Institute Inc. 1985). Unless otherwise specified, all analyses were conducted in program STATISTICA (StatSoft, Inc. 1994).

RESULTS

Habitat conditions varied considerably between 1994 and 1995. In 1994, NCHU was covered by a blanket of yellow sweet clover ranging in height from 2.3 to 15.2 dm (avg. = 7.4 dm, SE = 1.54). In 1994, there was lower forb diversity (avg. = 3.8 and 6.2 species in 1994 and 1995, respectively) (P = 0.0001). However, forbs were taller (avg. = 6.3 dm in 1994 and 2.4 dm in 1995) (P = 0.0001) and more dense (17% and 9% forb coverage in 1994 and 1995, respectively) in 1994. Also, in 1994 grass diversity was greater (P = 0.001) and species were taller (avg. = 5.8 dm in 1994, and avg. = 3.9 dm in 1995) (P = 0.0001).

Productivity

Censusing, Capture, and Marking

In 1994, 9 to 12 sharp-tailed grouse males were present on 4 dancing grounds (avg. = 10.3, SE = 1.26). In 1995, 16 to 21 males attended each of the 4 grounds (avg. = 18, SE = 2.16). One male attended 2 different grounds that were approximately 4-km apart. In 1994, a 5-day snow storm prevented me from estimating the peak number of females attending grounds. In 1995, the peak of female attendance at dancing grounds occurred from 15 April to 20 April, and as many as 12 females were observed with 21 males on a dancing ground. During 27 trap-mornings in 1994-95, I captured and radiomarked 42 females on 4 dancing grounds (Table 1). One female was captured on 2 different dancing grounds within 10 days. A second female was captured on the same dancing ground twice within 9 days, and a third female made 3 visits to one dancing

Table 1. Annual sharp-tailed grouse trapping results at Charles M. Russell NWR, Montana, 1994-1995.

	Males			Females			Total
Year	adult	yearling	recapture[a]	adult	yearling	recapture	Captures
1994	20	20	23	9	7	3	82
1995	13	20	27	11	15	0	86
Total	33	40	50	20	22	3	168

[a] recapture = the number of sharp-tailed grouse captured >1 time in a given trapping season.

ground before being killed by an avian predator. Of the 42 radiomarked females, 4 left the study area, and 2 carried faulty radios. The remaining 36 females provided nest, brood, and /or survival data. In 1995, I relocated 4 hens that had been radio-marked in 1994.

Nest Data

I found 31 nests, which included nests for 26 different hens. This sample included nests from 21 initial and 10 renesting attempts. Females began nesting on 28 April in 1994 and 30 April in 1995. Mean date for initial attempts was similar between years (Table 2). The earliest renest attempt was initiated on 11 May (1994), and the latest was initiated on 10 June (1995). The length of time between a female losing or abandoning a nest and initiating another ranged from 3 to 8 days and averaged 6 days (SE = 2.88). Thirteen females renested once and 1 female renested twice.

Three of 4 females monitored in both years displayed between-year nest-site fidelity. Females did not consistently exhibit fidelity to nesting habitat, however. One female nested <50 m from the previous year's nest, nesting in yellow sweet clover in 1994 and under a juniper in 1995. A second female nested 90 m from the previous year's nest, nesting in sagebrush in 1994 and grass in 1995. In 1995, this female nested twice in the same nest bowl. A third female nested 250 m from her previous year's nest, nesting in grass in 1994 and sagebrush in 1995.

Mean clutch size did not differ (P = 0.22) by year (Table 2) or by female age (avg. = 12.9, SE = 1.68 - adults; avg. = 12.1, SE = 2.46 - yearlings; P = 0.63). Clutch size ranged from 6 (n = 2) to 16 eggs (n = 2) and averaged 12.2 (SE = 2.3).

Nest success was 92% in 1994 and significantly lower (53%) in 1995 (P = 0.05). Nest success did not differ (P = 0.30) for adult (60%, n = 15) and yearling females (85%, n = 8). Hen success for all hens that remained on the area (n = 37) was 61% and did not differ (P = 0.28) between 1994 (79%) and 1995 (43%). Hen survival from trapping through nesting averaged 75% over both years and did not differ (P = 0.60) between 1994 (87% of 15 females) and 1995 (62% of 29 females). Three of 46 females (7%) died prior to nesting and 13 of 37 females (35%) died while nesting during the 2 years. Examinations of carcasses indicated that canid predation accounted for 57% of deaths. Two females were found dead at nest sites and appeared to have been bitten by prairie rattlesnakes. In both years, hen survival was 100% during the brood rearing period. On average, 75% of all females survived the entire breeding season (87% in 1994; 62% in 1995).

The earliest date of hatching was 7 June, and mean date of hatching was 18 June in both years (SE = 11.6, 1994; 9.4, 1995). Hatching was delayed by up to 5 days in 6 nests in 1995. I monitored these nests daily because they were incubated beyond their expected hatch dates. I suspect the delay was correlated with cold, wet weather that occurred continuously throughout the nesting period. Domestic livestock destroyed 2 renests. In successful nests, 90% of 126 eggs hatched in 1994, and 90% of 137 eggs hatched in 1995.

Table 2. Annual sharp-tailed grouse nesting data at Charles M. Russell NWR, Montana, 1994-1995.

	Sample sizes											
	Hens		Nests		Initiation Date[a]		Clutch Size		Nest Success[b]		Hatch Date	
Year	yearling	adult	initial	renest	avg.	SE	avg.	SE	avg.	SE	avg.	SE
1994	7	9	7	5	3 May[c]	4.07	11.6[d]	1.56	0.92[e]	0.08	18 June	11.6
1995	15	11	14	5	5 May	3.35	12.6	2.63	0.53	0.12	18 June	9.4
Total[f]	22	20	21	10	4 May	1.00	12.2	2.30	0.68	0.09	18 June	1.0

[a] Mean initiation data for first nesting attempts (75%and 76% of all nests initiated in 1994 and 1995, respectively).
[b] Proportion of nests that hatched ≥1 egg.
[c] X^2-test indicated no difference ($P = 0.8$) between years.
[d] T-test indicated no difference ($P = 0.22$) between years.
[e] X^2-test indicated an annual difference ($P = 0.048$).
[f] Equal weighting of annual means, standard error of annual means.

Brood Data

I collected data for 21 broods from 18 different females (11 broods in 1994, 10 broods in 1995) (Table 3). Mean brood size at hatching averaged 11.3 (SE = 1.0) and did not differ by year ($P = 0.18$). Chick survival differed ($P = 0.05$) by year and was higher in 1994 (44%) than in 1995 (9%). Because of total brood loss, apparent survival of chicks (45%) was larger than actual survival (25%).

Of 21 broods, 10 broods reached the age of 56 days (7 broods in 1994, 3 broods in 1995). Brood survival averaged 47% and did not vary by year ($P = 0.59$). In 1994, 4 of the successful brood-rearing females were adults and 3 were yearlings. In 1995, all 3 successful brood-rearing females were yearlings. Ten of the 11 broods that died (4 in 1994 and 6 in 1995) did so within 3 weeks of hatching, apparently from effects (exposure and/or starvation) caused by cool, wet weather. Brood-rearing females were observed moving short distances (>50 m) to another coulee when domestic livestock approached.

Habitat Selection

Nest Habitat

I collected habitat data for 36 nest-sites, 68 NAR sites, and 140 NSAR sites during 1994-1995. In 1994, females nested in grass/shrub and shrub/grass cover types more than expected and in the forb/grass cover type less than expected ($P < 0.001$). In 1995, nests were distributed among cover types in proportion to their availability ($P > 0.2$). Twenty-three nests (63.9%) were under shrubs, 11 (30.1%) were in grass, and 2 (5.6%) were in forbs. Location of nest-sites in relation to aspect appeared to be a matter of female choice (Figure 1.).

Table 3. Survival data for sharp-tailed grouse broods and chicks at Charles M. Russell NWR, Montana, 1994-1995.

		No. Chicks Hatched[a]		Brood Survival[b]		Chick Survival[c]		No. Chicks Alive/ 56-Day Old Brood[d]		Apparent Survival[e]	
Year	n[f]	avg.	SE	avg.	SE	avg.	SE	avg.	SE	avg.	SE
1994	11	10.3	3.17	0.64	0.15[g]	0.44	0.15[h]	4.5	4.7[i]	0.60	0.17
1995	10	12.3	3.47	0.30	0.15	0.09	0.10	1.1	2.3	0.30	0.17
All[j]	21	11.3	1.00	0.47	0.11	0.25	0.10	2.8	2.4	0.45	0.11

[a] Average number of chicks hatched per brood.

[b] Proportion of broods that produced ≥1 56-day-old chick.

[c] Proportion of chicks alive per brood 56 days after hatching.

[d] Number of chicks alive per brood 56 days after hatching (range from 1 to 13).

[e] Chick survival estimated with data only from broods that produced ≥1 56-day-old chick (7 and 3 broods in 1994 and 1995, respectively).

[f] Number of broods monitored.

[g] Yate's-corrected X^2 test indicated no differences (P = 0.59) between years.

[h] Data transformed by arcsin-sqrt prior to conducting a t-test (P = 0.048).

[i] T-test indicated no differences (P = 0.055).

[j] Equal weighting of annual means, standard error of annual means.

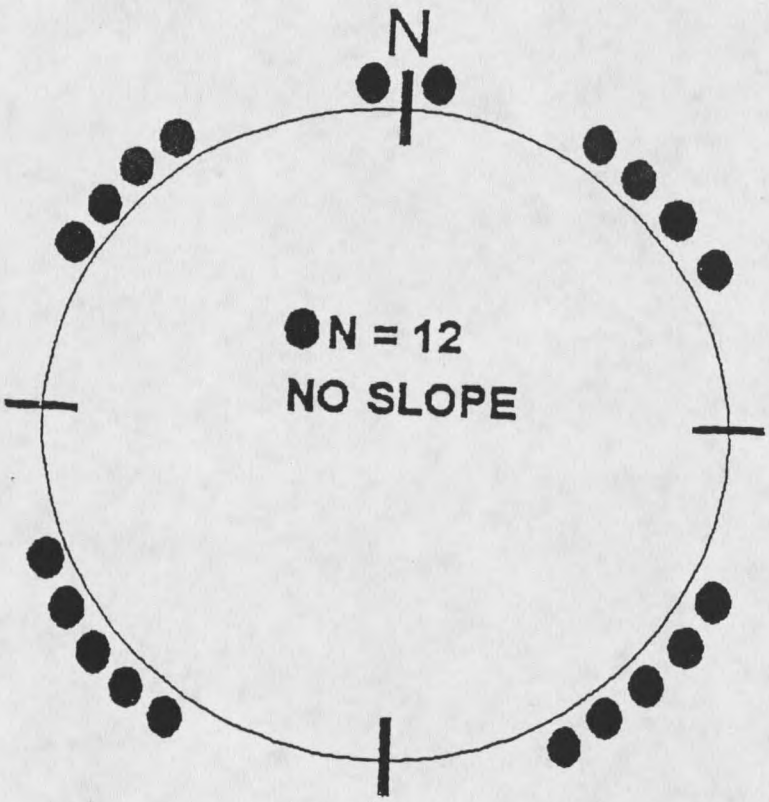

Figure 1. Aspect of sharp-tailed grouse nest-sites at the Charles M. Russell NWR, Montana, 1994-1995.

Most nests (58%) were found under big sagebrush (17 nests, avg. height = 42 cm, SE = 10.0) and Rocky Mountain juniper (4 nests, avg. height = 122 cm, SE = 65.0). Two nests were found under skunkbrush sumac (avg. height = 41 cm, SE = 3.7). Most nests ($\underline{n}$ = 8) in grassland were located in residual growth bluebunch wheatgrass (avg. height = 62 cm, SE = 8.0) and western wheatgrass (3 nests, avg. height = 51 cm, SE = 3.0). Residual growth of yellow sweet clover (avg. height = 80 cm, SE = 23.0) was the only forb used for nesting (2 nests). Screening height of vegetation at nests averaged 21 cm (SE = 2.8) and did not differ ($\underline{P}$ = 0.25) between 1994 (19 cm, SE = 7.2) and 1995 (23 cm , SE = 11.6). In 1994, 25% ($\underline{n}$ = 12) nesting females inhabited the breaks, while no females nested in the breaks in 1995.

Univariate Analysis. Univariate analyses indicated no differences between nest sites and NAR's or NSAR's in 1994 when yellow sweet clover bloomed. However, in 1995 screening-cover height was greater at nest sites than at either type of random site. Also, nest sites had more forbs and taller grass than NSAR's (Table 4) in 1995. Univariate analyses indicated no differences between successful and unsuccessful nest sites (Table 5).

Multivariate Analysis. Multivariate analyses comparing nest sites to random sites yielded similar results to univariate tests comparing characteristics of nest sites and random sites. In 1994, multivariate logistic regression comparing nest sites and NAR sites failed to produce a model. In 1995, the most parsimonious model produced by logistic regression for comparisons of nest sites with NAR sites contained cover density ($\underline{P} < 0.001$) (Table 6). Logistic regression indicated that there were more shrubs and/or greater forb diversity

Table 4. Results of univariate analyses of habitat variables comparing sharp-tailed grouse nest-site habitat to random habitat sites at the Charles M. Russell NWR, Montana, 1994-1995.

	1994							1995						
	Nest Site[a]		NAR Site		NSAR Site			Nest Site		NAR Site		NSAR Site		
Explan var.[b]	avg.	SE	avg.	SE	avg.	SE	P[c]	avg.	SE	avg.	SE	avg.	SE	P[c]
NUMSH	5.7	3.18	4.3	2.8	3.3	1.68	0.04	4.4	3.58	3.1	1.67	3.1	2.17	0.05
NUMFB	5.8	4.02	5.8	4.29	4.7	2.58	0.56	1.8	0.75	2.8	1.86	2.2	2.04	0.16
NUMGR	7.6	3.13	6.8	2.8	7.3	1.13	0.63	7.1	2.68	6.8	2.73	7.9	3.14	0.09
COVDEN	77.0	19.1	62.0	24.8	66.7	21.6	0.18	67.0	18.1	43.0	26.7	42.0	31.1	0.01
DSHHT	58.4	46.5	40.6	26.7	40.6	30.2	0.30	48.3	44.2	38.1	37.1	38.1	31.2	0.46
NOSHSP	2.7	1.4	2.5	1.4	1.9	0.8	0.14	2.7	1.0	2.5	1.2	2.4	1.2	0.42
DFBHT	63.9	28.4	50.8	26.9	48.3	27.7	0.25	22.9	10.4	25.4	14.5	25.4	19.1	0.69
NOFBSP	2.5	1.1	3.3	1.8	2.9	1.3	0.22	6.9	2.7A[d]	7.0	3.3AB	4.5	2.4C	0.001*
DGRHT	48.3	17.0	48.3	21.6	43.2	14.0	0.67	35.6	10.7A	33.0	16.3AB	25.4	11.7C	0.001*
NOGRSP	2.5	1.05	2.7	1.0	2.1	0.76	0.07	2.6	0.84	2.8	0.96	2.8	0.95	0.62
HDPAVG	19.1	7.2						23.1	11.6A	14.0	11.9B	11.3	10.3B	0.001*

[a] Nest-sites, NAR sites (associated random site: randomly located ≤100m from nest-site), and NSAR sites (study area random site: randomly located within study area) were evaluated using 0.04 ha circular plots (22.5 m dia.).

Table 4. (continued)

[b] NUMSH = amount of shrubs (m) present.
NUMFB = amount of forbs (m) present.
DSHHT = average dominant shrub height (cm).
NUMGR = amount of grass (m) present.
COVDEN = cover density estimated at 0.3 m in height with a cover density board.
NOSHSP = number of shrub species.
DFBHT = average dominant forb height (cm).
NOFBSP = number of forb species.
DGRHT = average dominant grass height (cm).
NOGRSP = number of grass species.
HDPAVG = height density pole reading measuring screening cover height (cm) above nest bowl.

[c] Significance level for Anova test: Because 11 variables measured on the same plots were used to test for vegetative differences, Bonferroni-corrected significance is set at 0.005 (0.05 divided by 11). P-values marked with an asterisk were significant at the 0.005 level.

[d] When results of ANOVA were significant, I did multiple comparisons to isolate differences. Within a year and row, means sharing the same capital letter are not significantly different.

Table 5. Results of univariate analyses of habitat variables comparing sharp-tailed grouse successful nests to unsuccessful nests at the Charles M. Russell NWR, Montana, 1994-1995.

	Nest				
	Successful		Unsuccessful		
Explan Var.[a]	avg.	SE	avg.	SE	P[b]
NUMSH	3.8	2.85	5.8	3.56	0.07
NUMFB	3.6	3.54	3.0	2.36	0.53
NUMGR	7.6	2.95	7.8	2.97	0.81
COVDEN	68.0	18.90	76.0	19.70	0.20
DSHHT	42.7	40.60	71.3	55.90	0.08
NOSHSP	2.7	1.20	2.6	1.20	0.69
DFBHT	39.4	22.40	42.2	35.60	0.80
NOFBSP	5.5	3.50	5.0	2.40	0.62
DGRHT	41.7	13.20	40.4	15.00	0.76
NOGRSP	2.6	0.75	2.6	1.09	0.97
HDP	19.3	10.5	26.4	13.08	0.04

[a]NUMSH = amount of shrubs (m) present.
NUMFB = amount of forbs (m) present.
NUMGR = amount of grass (m) present.
COVDEN = cover density estimated at 0.3 m in height with a cover density board.
DSHHT = average dominant shrub height (cm).
NOSHSP = number of shrub species.
DFBHT = average dominant forb height (cm).
NOFBSP = number of forb species.
DGRHT = average dominant grass height (cm).
NOGRSP = number of grass species.
HDPAVG = height density pole reading measuring screening cover height (cm) above nest bowl.

[b] Significance level for ANOVA test: Because 11 variables measured on the same nest plots were used to test for vegetative differences, Bonferroni-corrected significance is set at 0.005 (0.05 divided by 11). When I added the Bonferroni correction some significance was lost.

and grass height at nest sites than at NSAR sites in both years (Table 6). All models were significant but had low values for model fit (12-22% of log-likelihood explained by the model). In 1994, for comparisons of NAR sites with NSAR sites, logistic regression produced a model containing grass diversity ($P = 0.016$), which indicated that there was greater grass diversity at NAR sites. In 1995, the most parsimonious model produced by logistic regression comparing NAR sites with NSAR sites contained amount of grass, forb diversity, and grass height ($P < 0.001$). In 1995, NAR sites typically had greater forb diversity with less grass but taller grass plants. Fit of both models comparing NAR-NSAR sites was weak, however (9-20% of log-likelihood explained by the model).

Brood Habitat

During 1994-95, habitat data were collected for 207 brood sites, 207 BAR sites, and 175 BSAR sites (Table 7). When testing whether brood use of cover types was related to time of day, brood age, or time of year, I was only able to compute results for the 1994 brood data because of the limited number of broods and brood sites in 1995.

Brood use of cover varied by time of day ($X^2 = 24.04$, $P < 0.001$): (1) broods used grass/shrub cover significantly ($P < 0.05$) more than expected during morning and evening hours, and (2) broods used shrub/grass cover significantly ($P < 0.05$) more than in proportion to its availability during the mid-day hours. Brood use of cover also varied with age ($X^2 = 17.7$, $P < 0.001$). Broods <4 weeks old used forb/grass and grass/shrub cover more than expected ($P < 0.05$) and shrub/grass cover less than expected ($P < 0.05$). Older broods used shrub/grass cover more than expected ($P < 0.05$), while grass/shrub and

Table 6. Results of stepwise logistic regression of habitat variables related to sharp-tailed grouse nest-site selection at the Charles M. Russell NWR, Montana, 1994-1995.

Comparison	Year	No. of Sites	Logit[a]	P	DF	Fit[b]
N vs NAR[c]	1994	41	No variable entered the model	0.089	1	
N vs NSAR[d]	1994	35	-1.77 + 0.35(NUMSH)[i]	0.018	1	0.12
NAR vs NSAR[e]	1994	46	-1.71 + 0.83(NOGRSP)	0.016	1	0.09
N vs NAR[f]	1995	64	-3.83 + 3.74(COVDEN)	0.0002	1	0.16
N vs NSAR[g]	1995	142	-5.42 + 0.17(NUMSH) + O.24(NOFBSP) + 0.15(DGRHT)	0.0001	3	0.22
NAR vs NSAR[h]	1995	162	-2.93 - 0.15(NUMGR) + 0.29(NOFBSP) + 0.12(DGRHT)	0.0001	3	0.20

[a]Logit of the equation estimating the probability of a site being a nest site where the equation is: $e^{logit} / 1 + e^{logit}$.

[b]Fit was calculated as the Model X^2 divided by -2 ln log-likelihood of the null model and can be interpreted as the proportion of the log-likelihood explained by the model being tested (MATHSOFT,Inc 1994).

[c,d,e]NUMSH (P = 0.04), COVDEN (P = 0.18), NOSHSP (P = 0.14), DFBHT (P = 0.25), NOFBSP (P = 0.22), and NOGRSP (P = 0.07) were allowed entry to the regression.

[f,g,h]NUMSH (P = 0.05), NUMGR (P = 0.09), NUMFB (P = 0.16), COVDEN (P = 0.01), NOFBSP (P = 0.0001), and DGRHT (P = 0.0001) were allowed entry to the regression.

[i]COVDEN = cover density estimated at 0.3 m in height with a cover density board, NUMSH = amount of shrubs (m) present, NOFBSP = number of forb species, NOGRSP = number of grass species, NUMGR = amount of grass (m) present, DGRHT = average dominant grass height (cm).

Site type: N = nest site, NAR = associated random site (randomly located 5-100 m from nest), NSAR = study-area random site (randomly located within study area).

Table 7. Summary of brood vegetation plots at the Charles M. Russell NWR, Montana, 1994-1995.

	Site Type		
Year	Brood	BAR[a]	BSAR[b]
1994	173	173	55
1995	34	34	120
Total	207	207	175

[a]BAR = Associated random site (5-100 m from brood site).
[b]BSAR = Study area random site (randomly located within study area).

forb/grass cover were used less than expected based on availability ($P < 0.05$). Brood use of cover also varied with time of year ($X^2 = 12.1$, $P = 0.002$). Grass/shrub cover was used more than expected by broods from mid-June to mid-July ($P < 0.05$), and less than expected after mid-July ($P < 0.05$). Broods used shrub/grass cover less than expected based on habitat availability during the early period ($P < 0.05$), and more than expected during the late use period ($P < 0.05$). Forb/grass cover was used in proportion to availability during both periods ($P > 0.05$).

Univariate Analysis. Univariate analyses indicated that in both years brood sites contained more shrubs and had greater vegetative density than either type of random site ($P < 0.005$) (Table 8). In 1994, brood sites were characterized as having taller forbs and shrubs, and less grass than either type of random site ($P < 0.005$) (Table 8). Brood sites had greater shrub diversity than either type of random site in 1995 ($P < 0.005$) (Table 8).

Table 8. Results of univariate analyses of habitat variables comparing sharp-tailed grouse brood-site habitat to random habitat sites at the Charles M. Russell NWR, Montana, 1994-1995.

	1994							1995						
	Brood Site[a]		BAR Site		BSAR Site			Brood Site		BAR Site		BSAR Site		
Explan var.[b]	avg.	SE	avg.	SE	avg.	SE	P[c]	avg.	SE	avg.	SE	avg.	SE	P[c]
NUMSH	7.3	5.4A[d]	4.2	2.7B	5.5	2.9B	0.001*	5.3	3.4A	3.6	1.9B	3.3	2.4B	0.001*
NUMFB	3.8	2.8	3.7	2.4	3.5	2.8	0.64	2.1	1.7	2.2	1.7	1.7	1.3	0.16
NUMGR	7.1	3.3A	8.6	3.1B	8.2	3.0B	0.001*	6.6	2.8	6.9	2.4	7.7	3.6	0.19
COVDEN	77.0	22.8A	45.0	25.9B	54.0	32.0B	0.001*	76.0	22.8A	49.0	25.9B	42.0	32.0B	0.001*
DSHHT	88.9	71.1A	45.7	41.7B	55.9	73.4B	0.001*	76.2	69.9A	53.3	53.3AB	43.2	47.2B	0.003*
NOSHSP	2.9	1.4	2.8	1.2	2.3	1.0	0.01	3.4	1.2A	2.6	1.4B	2.3	1.1B	0.001*
DFBHT	63.5	24.9A	50.8	28.4B	45.7	29.0B	0.001*	25.4	11.7	25.4	11.9	20.3	14.0	0.29
NOFBSP	3.8	1.9	4.1	1.9	4.0	1.7	0.13	6.2	2.0A	6.0	2.4AB	3.9	2.3B	0.001*
DGRHT	58.4	20.6	50.8	20.1	53.3	16.3	0.01	38.1	15.7	38.1	16.8	35.6	14.3	0.19
NOGRSP	3.2	0.9	3.3	1.0	3.4	1.9	0.30	2.6	0.9	2.4	0.7	2.6	1.0	0.49

[a] Brood-sites, BAR sites (associated random site: randomly located 5-100m from brood-site), and BSAR sites (study area random site: randomly located within study area) were evaluated using 0.04 ha circular plots (22.5 m dia.).

[b] NUMSH = amount of shrubs (m) present.
NUMFB = amount of forbs (m) present.
NUMGR = amount of grass (m) present.

Table 8. (continued)

b (continued) DFBHT = average dominant forb height (cm).
COVDEN = cover density estimated at 0.3 m in height with a cover density board.
DSHHT = average dominant shrub height (cm).
NOSHSP = number of shrub species.
NOFBSP = number of forb species.
DGRHT = average dominant grass height (cm).
NOGRSP = number of grass species.

[c] Significance level for Anova test: Because 10 variables measured on the same plots were used to test for vegetative differences, Bonferroni-corrected significance is set at 0.005 (0.05 divided by 10). P-values marked with an asterisk were significant at the 0.005 level.

[d] When results of ANOVA were significant, I did multiple comparisons to isolate differences. Within a year and row, means sharing the same capital letter are not significantly different.

Multivariate Analysis. In both years and for comparisons of brood sites with each type of random site, logistic regression produced models containing different variables (Table 9). However, cover density was present in all models and indicated that brood sites had greater vegetative density than either type of random site. Fit of the models, however, was weak (7-31% of log-likelihood explained by the model). In 1994, the most parsimonious model produced by logistic regression for comparisons of BAR sites with BSAR sites contained number of shrubs and shrub diversity ($P < 0.001$) (Table 9), which indicated that BAR sites contained fewer shrubs but greater shrub diversity. In 1995, for comparisons of BAR sites with BSAR sites, logistic regression produced a model with forb diversity ($P < 0.001$) (Table 9), which indicated that there was greater forb diversity found at BAR sites. Fit of both BAR-BSAR models was weak, however (7-12% of log-likelihood explained by the model).

Movement and Home Range Data

Dispersal distances from the dancing ground to a female's first nest site averaged 3.3 km (SE = 2.6, $n = 16$) in 1994 and 2.4 km (SE = 1.44, $n = 20$) in 1995. Two females exhibited extreme dispersal: 21 km and 26 km. Only 31% of females nested <1.6 km from where they were trapped. Most (58%) females nested closer to a dancing ground other than the one where they were captured (1994 - 56%, avg. = 1.2 km, SE = 0.72; 1995 - 60%, avg. = 1.9 km, SE = 1.1).

Home range sizes were only estimated for the brood-rearing period in 1994 due to the limited number of locations per brood in 1995. Home range sizes for 6 brood-rearing females ranged from 25 to 271 ha and averaged 143 ha (SE = 83, adaptive kernel). Minimum convex polygons for these females

Table 9. Results of stepwise logistic regression of habitat variables related to sharp-tailed grouse brood-site selection at the Charles M. Russell NWR, Montana, 1994-1995.

Comparison	Year	No. of Sites	Logit[a]	P	DF	Fit[b]
B vs BAR[c]	1994	346	-3.46 + 3.64(COVDEN)i	0.0001	1	0.21
B vs BSAR[d]	1994	228	-2.33 + 2.56(COVDEN) + 0.36(NOSHSP)	0.0001	2	0.15
BAR vs BSAR[e]	1994	228	0.80 - 0.20(NUMSH) + 0.51(NOSHSP)	0.0001	2	0.07
B vs BAR[f]	1995	68	-4.26 + 3.04(COVDEN) + 0.46(NOSHSP)	0.0001	2	0.22
B vs BSAR[g]	1995	155	-4.33 + 2.53(COVDEN) + 0.44(NOFBSP) - 0.20(NUMGR)	0.0001	3	0.31
BAR vs BSAR[h]	1995	155	-2.96 + 0.35(NOFBSP)	0.0001	1	0.12

[a]Logit of the equation estimating the probability of a site being a brood site where the equation is: $e^{logit} / 1 + e^{logit}$.

[b]Fit was calculated as the Model X^2 divided by -2 ln log-likelihood of the null model and can be interpreted as the proportion of the log-likelihood explained by the model being tested (MATHSOFT, Inc., 1994).

[c,d,e]NUMSH (P = 0.0001), NUMGR (P = 0.0001), COVDEN (P = 0.0001), DSHHT (P = 0.0001), NOSHSP (P = 0.01), DFBHT (P = 0.0001), NOFBSP (P = 0.13), and DGRHT (P = 0.01) were allowed entry to the regression.

[f,g,h]NUMSH (P = 0.0003), NUMGR (P = 0.19), NUMFB (P = 0.16), COVDEN (P = 0.0001), DSHHT (P = 0.003), NOSHSP (P = 0.0001), NOFBSP (P = 0.0001), and DGRHT (P = 0.19) were allowed entry to the regression.

[i]COVDEN = cover density estimated at 0.3 m in height with a cover density board, NOSHSP = number of shrub species, NUMSH = amount of shrubs (m) present, NOFBSP = number of forb species, NUMGR = amount of grass (m) present.

Site type: B = brood site, BAR = associated random site (randomly located 5-100 m from brood-site), BSAR = study area random site (randomly located within study area).

ranged from 14 to 185 ha and averaged 86 ha (SE = 64). Broods remained near nest sites the first few days after hatching and typically dispersed gradually from the nesting area.

Broods occasionally made large moves. Two females with 6-day-old broods moved 2.4 km away from nest sites. Each brood-rearing female moved back to the area where she had nested when broods were approximately 4 weeks old. In 1994, 4 hens that nested and reared broods in the Missouri breaks all moved from the lower breaks onto the uplands (100 m in elevation) within 3 days of one another. This move occurred at the same time that large numbers of shorthorned (Family Acrididae) and longhorned grasshoppers (Family Tettigoniidae) also moved from the breaks to the uplands.

DISCUSSION

Productivity

Nest Data

Most (75%) females initiated nests within the first week in May, which is similar to dates reported by others (Christenson 1970, Gunderson 1990, Meints 1991). Mean clutch size (12.2 eggs) for both years was slightly lower than the 13.2 eggs reported by Gunderson (1990) but similar to averages in other studies (Hamerstrom 1939, Brown 1967a, Artman 1970, Kobriger 1980, Meints 1991). Similarly, egg hatchability for this study (90%) compares favorably with rates from other studies (Artman 1970, Gunderson 1990).

Nest success in 1994 (92%) was higher than that reported by any other sharp-tailed grouse study. Nest success in 1995 (53%), however, was quite similar to nest success reported by others (Hamerstrom 1939, Artman 1970, Christenson 1970, Marks and Marks 1987a, Sisson 1976, Kobriger 1980). I suspect that lower nest success in 1995 was partially caused by heavy precipitation (19.8 cm) received during May and June. During such weather, hen's may have been unable to maintain temperatures within the range (35-40.5 ^{o}C) (Gill 1990:354) required for incubating, which may have caused embryonic development to slow or cease. There was also an increase in nest predation (n = 5 nests) by coyotes in 1995. New growth of yellow sweet clover during nesting in 1994 may have helped conceal nests by limiting the radiation of female scent from the nest site and/or may have blanketed the clumpy appearance of shrubs (predators seem to key in on) common with shrubsteppe habitat.

Another possible explanation for the difference in nest success may have been related to a switch in prey species by coyotes. CMRNWR experienced a severe decline in mule deer (Odocoileous hemionus) abundance during the winter of 1993-94 (Mackie pers. commun.). Coyotes may have switched to feeding on mule deer carrion, which may have led to a decrease in nest predation, i. e., greater nest success in 1994.

The 2-year hen success rate (61%) recorded in this study is similar to estimates in Montana (65%) (Gunderson 1990) and North Dakota (55%) (Kobriger 1980). Meints (1991) reported a hen success rate of 86% for the Columbian subspecies. Hen survival during the nesting season was 75%. Based on examinations of carcasses and bite marks on radio transmitters, I concluded that most (57%) hens were killed by coyotes. Two females were apparently killed by rattlesnake bites, which is a mortality source that has never been documented. All hens that survived the nesting season, also survived the rest of the summer in both years. This is contrary to what has previously been reported. Others have noted deaths of brood-rearing females and indicated that conspicuousness of brood females leads them to having higher mortality rates than females not rearing broods (Christenson 1970, Bergerud and Gratson 1988a, Gunderson 1990). High post-nesting survival rates of females in this study cannot be fully understood. Perhaps chicks were sacrificed during encounters with predators while hens escaped and/or predators may have switched to another prey species, e. g., voles (Microtus spp) during the brood-rearing period .

Brood Data

During this study, 10 of 21 broods and 60 of 236 chicks survived to the age of 56 days. Although causes of chick mortality could not be determined, most losses were correlated with the timing of cold, wet weather. Thus, it appears that the main factor limiting sharp-tailed grouse chick production was cold, wet weather during the early brood-rearing period. MacMullan and Eberhardt (1953) studying pheasants (Phasianus colchicus) reported that conceivably, severe cold, especially in conjunction with precipitation, could cause widespread mortality, if it occurred at a time when a large proportion of the chick population was vulnerable. Reportedly, young chicks that are unable to thermoregulate are also suseptible to starvation during periods of cold, wet weather because they have high metabolic rates and may become to lethargic (cold) to forage (Bergerud 1988b). Brown (1967a) reported 50% chick mortality during the first 3 weeks of life in early sharp-tailed grouse broods. Bergerud (1988b) also noted chick mortality in Michigan (36%). In my study, chick survival varied by year and was higher in 1994 (44%). To prevent overestimating chick survival, I took into account the entire loss of broods. I am unaware of any other sharp-tailed grouse study that has taken into account total brood losses when estimating chick survival or mortality. Whether or not Brown (1967a) did is uncertain. Mean brood size in 1994 (4.5) was similar to the 4.5 reported for Saskatchewan (Symington and Harper 1957) and the 4.5 (Marks and Marks 1987a) and 4.1 (Meints 1991) for Idaho.

Habitat Selection

Nest Data

On the uplands where bunchgrasses were rare and big sagebrush dominated (average canopy height of 42 cm), sharp-tailed grouse nested under shrubs. Females did nest in residual growth of bluebunch wheatgrass in the breaks, however. Christenson (1970) reported that nesting sharp-tailed grouse require uniform vegetation ≥30 cm high or patchy vegetation >36 cm high. Kobriger (1980) concluded that hens nested in woody cover within pastures when grassy areas were too short to provide adequate nesting cover. In the absence of grass of adequate height, Nielsen and Yde (1982) found sharp-tailed grouse using shrubs for nesting. Gunderson (1990) also reported females using shrubs (average canopy height of 47 cm).

In my study aspect was, apparently, not an important parameter considered by females when selecting nest-sites. Gunderson (1990) reported similar results which suggests that sharp-tailed grouse nest-site selection is not dependent on aspect.

To the best of my knowledge, no studies on plains sharp-tailed grouse have examined differences between successful and unsuccessful nests, and only Meints (1991) did this with the Columbian subspecies. In my study, no significant differences were found between the 2 nest types. However, means for individual vegetative variables suggest that unsuccessful nests were more often found in tall, dense stands of sagebrush or isolated juniper bushes, which may stand out and tend to attract predators.

Brood Data

Although nesting females predominantly used shrubs, females with young broods shifted use to areas with new grass and yellow sweet clover growth, which are likely areas with high insect densities. Older broods selected for areas with greater densities of big sagebrush and juniper. The heavy use of shrub habitat by older broods was probably not related to dietary changes. Rather, the extreme temperatures that occur during the late brood-rearing period likely cause broods to seek out the cooler microclimate provided by shrubs. Other studies have also reported that broods move to denser cover later in the summer (Edminster 1954, Peterle 1954, Ammann 1957).

Brood habitat use also varied with time of day. Broods used grass/shrub cover during the early morning and evening hours for feeding and shrub/grass cover for dusting and roosting during mid-day. Similar daily use patterns were found in other studies (Marshall and Jensen 1937, Christenson 1970, Pepper 1972, Gunderson 1990). Although I did not record data for temperature versus brood habitat use, I did notice that at temperatures >29 ^{o}C grouse broods used dense stands of Rocky Mountain juniper almost exclusively. However, when temperatures dropped to <26 ^{o}C, e. g., on cloudy days, broods were typically found using big sagebrush. Thus, big sagebrush apparently does not provide adequate shelter from extreme temperatures. Another possible explanation is that broods may stand a better chance of avoiding predators when chicks are scattered in sagebrush rather than in stands of juniper which are typically in or along coulees, i. e., predator runways.

Brood sites contained more shrubs and had greater vegetational cover density than either type of random site. Other studies have reported the

importance of shrub cover and cover density to broods also (Kobriger 1980, Oedekoven 1985, Klott and Lindzey 1990, Meints 1991, Cope 1992). Thus, habitat management for broods should emphasize increasing values for these habitat variables.

Domestic livestock are grazed on NCHU between 1 June and early September each year. Mackie (1978) reported that 82% of 25,000 livestock observations on the CMRNWR occurred in areas with <10% slope and <1.2 km from water. In my study, 81% of nests and 52% of brood locations also occurred in such areas. Thus grouse nests, broods, and cattle occupied the same areas. I noted 2 cases of direct evidence of cattle negatively affecting grouse by trampling nests. I also noted indirect evidence of cattle affecting grouse. Grouse broods were observed moving short distances (>50 m) when cattle approached, however, they did not leave pastures occupied by livestock. Although results of my study indicated sharp-tailed grouse can have good productivity (1994) with domestic livestock present, there was evidence of incompatibility (1995). However, the level of incompatibility could not be estimated because I did not have control areas for making comparisons of grouse density and productivity in areas with and without domestic livestock. Thus, further research is needed using controls and various treatment levels of livestock use to address compatibility issues.

Excessive grazing by domestic livestock has been documented as having adverse effects on sharp-tailed grouse populations in North Dakota (Aldous 1943, Christenson 1970, Manske et al. 1988). However, the level at which livestock grazing becomes detrimental to sharp-tailed grouse is unknown. Christenson (1970) proposed that grazing be regulated to maintain ≥30 cm of

uniform vegetative cover for sharp-tailed grouse propagation. In North Dakota, Kirsch (1974) and Eng et al. (1987) reported that grasslands should be managed to maintain 15-50 cm of residual cover for prairie chickens (Tympanuchus cupido). Brown (1978) stated that even a conservative utilization of forage in the neighborhood of 20-40% could be highly detrimental to grassland birds during drought periods because it could remove critical cover for next year. My study indicates that grazing should be regulated to maintain ≥20 cm of uniform residual vegetation or patchy vegetation >42 cm tall for sharp-tailed grouse propagation.

Habitat parameters required for quality sharp-tailed grouse production in shrubsteppe avifauna were apparently met in my study. However, more studies are needed to verify the results of this study so that managers can effectively manage sharp-tailed grouse populations in shrubsteppe plant communities. In particular, there is a need for larger samples (greater number of birds and more nest and brood locations) to increase statistical power. In my study, I likely made some Type II errors when comparing used sites with random sites, i. e., failed to detect differences that existed.

Movements and Home range

Females in my study typically nested farther from the dancing ground where they were captured than the <1.6 km average reported by others (Hamerstrom 1939, Symington and Harper 1957, Artman 1970, Kobriger 1980, Marks and Marks 1987a, Gratson 1988a). Also, females usually nested closer to a dancing ground other than the one where they were captured. Others have also reported females nesting closer to other dancing grounds (Artman 1970,

Christenson 1970, Gunderson 1990). I captured 1 female on 2 different dancing grounds, which has only been previously reported for Wisconsin (Gratson 1988a).

Three of 4 females studied in both years nested <250 m from the previous year's nest in the second year. Similar nest-site fidelity was also reported by Gunderson (1990) for the eastern part of the CMRNWR but has not been reported for sharp-tailed grouse populations elsewhere. Fidelity to nesting cover was not as common, however. I am unaware of other studies that investigated fidelity to cover type among nesting attempts.

Brood home-range sizes were larger (143 ha) when analyzed with adaptive kernel than minimum convex polygons (86 ha). Home range sizes estimated by minimum convex polygons are widespread throughout the literature. However, when home range is estimated by this method home-range size is highly correlated with sample size of locations. Sample size in this study was 30 locations per brood. Therefore, I also used adaptive kernel to obtain a more precise estimate of home range size. Using minimum convex polygons for comparative purposes, brood home ranges in my study were considerably smaller than the 433 ha reported for the eastern part of the CMRNWR (Gunderson 1990) but similar to sizes reported in Minnesota (55 ha) (Artman 1970) and Wisconsin (65 ha) (Gratson 1988a). The small brood ranges in this study may be due to the high level of vegetational heterogeneity in NCHU, which would indicate that broods do not need to travel long distances to meet their habitat needs.

MANAGEMENT IMPLICATIONS

The objective of CMRNWR is to achieve habitat occupancy by sharp-tailed grouse. The following guidelines are provided for maintaining or increasing numbers of sharp-tailed grouse within the framework of established land-use practices.

1. Refuge personnel should concentrate sharp-tailed grouse census efforts between 15 April and 1 May (peak of the breeding season). For accurate counts, birds on dancing grounds should be counted a minimum of 3 different times. Censusing should be conducted from 0.5 hr before day break to 0930 hr. Most females attend grounds between 0600 and 0800 hr. In addition, listening routes should be used to locate new grounds.

2. Christenson (1970) reported that nesting sharp-tailed grouse require uniform vegetation $\geq$30 cm high or patchy vegetation >36 cm high. Results of my study suggest that vegetation should be managed to maintain a visual obstruction height of at least 20 cm and canopy heights $\geq$ 42 cm for nesting sharp-tailed grouse. Nesting occurred in a variety of cover types (bunchgrasses, sagebrush, juniper, and skunkbrush sumac) and appears to be a matter of female preference. Thus, managers should strive to maintain a variety of cover types with screening cover heights of at least 20 cm.

3. In my study, nest sites and brood sites contained greater cover density and more shrubs than either type of random site. Similarly, Kobriger (1980), Geisen (1987), Marks and Marks (1987a), and Meints (1991) indicated that hens selected nest sites with denser cover and/or greater density of shrubs than found at random sites. In addition, several studies have reported denser cover

and/or greater density of shrubs at sites used by sharp-tailed grouse broods than at random sites (Kobriger 1980, Oedekoven 1985, Klott and Lindzey 1990, and Cope 1992). Thus, management for dense cover and dense shrubs, should benefit sharp-tailed grouse productivity. Sharp-tailed grouse may benefit if managers consider setting aside some of the more productive vegetative areas that would enhance sharp-tailed grouse production if left undisturbed for more than 1 year, i. e., habitat enclosures.

4. Older broods used dense stands of juniper ≥1.5 m in height almost exclusively at temperatures >29 ^{o}C. Thus, juniper pockets, should be maintained and preserved, perhaps, even to the extent of performing active fire suppression in this cover type when possible.

5. This study did not address long-term effects of domestic livestock grazing on sharp-tailed grouse habitat. Studies have shown that domestic livestock have the potential for adversely affecting sharp-tailed grouse populations in North Dakota (Aldous 1943, Christenson 1970, Manske et al. 1988). Combining Mackie's (1978) observations on livestock and my observations on sharp-tailed grouse, it is evident that the 2 species cohabitate, usually in areas with high primary productivity. Thus, the potential exists for conflicts during drought conditions. Brown (1978) stated that utilization of 20-40% of forage could be highly detrimental to grassland birds during drought periods because it could remove cover that may be critical in the next year. If current livestock grazing removes vegetative cover below the 20 cm screening height, management actions should be taken in the form of reducing cattle stocking rates or setting aside some of the more productive grouse habitat areas.

LITERATURE CITED

Aldous, S. E. 1943. Sharp-tailed grouse in the sand dune country of north-central North Dakota. J. Wildl. Manage. 7:23-31.

Aldrich, J. W. 1963. Geographic orientation of American Tetraonidae. J. Wildl. Manage. 27:529-545.

Ammann, G. A. 1944. Determining age of pinnated and sharp-tailed grouse. J. Wildl. Manage. 8:170-171.

_____. 1957. The prairie grouse of Michigan. Michigan Dept. of Conserv. Tech. Bull., Lansing. 200 pp.

Artman, J. W. 1970. Spring and summer ecology of the sharp-tailed grouse. Ph.D. Thesis, Univ. of Minn., St. Paul. 129 pp.

Bergerud, A. T. 1988b. Population ecology of North American grouse. Pages 578-685 in A. T. Bergerud and M. W. Gratson, eds. Adaptive strategies and population ecology of northern grouse. Univ. of Minn. Press, Minneapolis. 809 pp.

_____., and M. W. Gratson. 1988a. Survival and breeding strategies of grouse. Pages 473-577 in A. T. Bergerud and M. W. Gratson, eds. Adaptive strategies and population ecology of northern grouse. Univ. of Minn. Press, Minneapolis. 809 pp.

Brown, R. L. 1967a. Sharp-tailed grouse population study. Montana Fish and Game Dept. Proj. W-91-R-9, Job II-E. Mimeo. 16 pp.

Brown, D. E. 1978. Grazing, grassland cover and gamebirds. Trans. N. A. Wildl. Nat. Res. Conf. 43:477-485.

Christenson, C. D. 1970. Nesting and brooding characteristics of sharp-tailed grouse (Pedioecetes phasianellus jamesi Lincoln) in southwestern North Dakota. M.S. Thesis, Univ. of North Dakota, Grand Forks. 53 pp.

Cope, M. G. 1992. Distribution, habitat selection, and survival of transplanted Columbian sharp-tailed grouse in the Tobacco Valley, Montana. M.S. Thesis. Mont. State Univ., Bozeman. 60 pp.

Dorn, R. D. 1984. Vascular plants of Montana. Mountain West Publishing, Cheyenne, Wyo. 276 pp.

Edminster, F. C. 1954. American game birds of field and forest: their habits, ecology and management. Chas. Scribner's Sons, N.Y. 490 pp.

Eng, R. L., J. E. Toepfer, and J. A. Newell. 1987. Management of livestock to improve and maintain prairie chicken habitat on the Sheyenne National Grasslands. Pages 55-57 in A. J. Bjugstad, tech. coord., Prairie chickens on the Sheyenne National Grasslands. U.S. For. Serv. and Range Exp. Sta. Gen. Tech. Rep. RM-159.

Geisen, K. M. 1983. Population characteristics and habitat requirements of Columbian sharp-tailed grouse in northern Colorado. Pages 67-75 in Colorado. Div. of Wildlife., Wildl. Research Report No. CO W-037-R-36 / Wk. Pl. 13 / Job 08. 67-75 pp.

_____. 1987. Population characteristics and habitat use by Columbian sharp-tailed grouse in northwest Colorado. Project No. W-37-R. Pages 251-280 in Colorado Div. of Wildl., Wildl. Research Report, April 1987.

Gill, F. B. 1990. Ornithology. W. H. Freeman and Company, New York, N.Y. 643 pp.

Gratson, M. W. 1988a. Spatial patterns, movements, and cover selection by sharp-tailed grouse. Pages 158-192. in A. T. Bergerud and M. W. Gratson, eds. Adaptive strategies and population ecology of northern grouse. Univ. of Minn. Press, Minneapolis. 809 pp.

Gunderson, P. T. 1990. Nesting and brood rearing ecology of sharp-tailed grouse on the Charles M. Russell National Wildlife Refuge. M.S. Thesis, Mont. State Univ., Bozeman. 86 pp.

Hamerstrom, F. N., Jr. 1939. A study of Wisconsin prairie chicken and sharp-tailed grouse. Wilson Bull. 51:105-120.

_____. 1963. Sharptail brood habitat in Wisconsin's Northern Pine Barrens. J. Wildl. Manage. 27(4):793-801.

Henderson, R. F., F. W. Brooks, R. E. Wood, and R. B. Dahlgren. 1967. Sexing of prairie grouse by crown feather patterns. J. Wildl. Manage. 31:764-769.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the Pacific Northwest. Univ. of Wash. Press, Seattle. 730 pp.

Hoag, A. W. and C. E. Braun. 1990. Status and distribution of plains sharp-tailed grouse in Colorado. Prairie Nat. 22(2):97-102.

Hosmer, D. W., Jr., and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, New York, N.Y. 107 pp.

Johnsgard, P. A. 1975. North American game birds of upland and shoreline. Univ. Nebraska Press, Lincoln. 183 pp.

_____. 1983 Grouse of the world. Univ. of Nebr. Press, Lincoln. 413

Kie, J. G., J. A. Baldwin, and C. J. Evans. 1994. CALHOME: Home range analysis program electronic user's manual. U.S. Dep. of Agr., Forest Service, Fresno, CA. 17 pp.

Kirsch, L. M., A. T. Klett, and H. W. Miller. 1973. Land use and prairie grouse population relationships in North Dakota. J. Wildl. Manage. 37:449-453.

_____. 1974. Habitat management considerations for prairie chickens. Wildl. Soc. Bull. 2:124-129.

Klott, J. H., and F. G. Lindzey. 1990. Brood habitats of sympatric sage grouse and Columbian sharp-tailed grouse in Wyoming. J. Wildl. Manage. 54(1):84-88.

Kobriger, G. D. 1978. The 1977 annual report on sharp-tailed grouse. North Dakota Outdoors, Vol. XXXX, No. 7, p. 2-3.

_____. 1980. Habitat use by nesting and brooding sharp-tailed grouse in southwestern North Dakota. N. D. Outdoors 43:2-6.

Kohn, S. C. 1976. Sharp-tailed grouse nesting and breeding habitat on southwestern North Dakota. M.S. Thesis. South Dakota State Univ., Brookings. 66 pp.

Mackie, R. J. 1978. Impacts of grazing on wild ungulates. Presented at N. Amer. Wildl. and Nat. Res. Conf., Phoenix, AZ. 32 pp.

MacMullan, R. A., and L. L. Eberhardt. 1953. Tolerance of incubating pheasant eggs to exposure. J. Wildl. Manage. 17:322-330.

Manske, L. L., W. T. Barker, and M. E. Biondini. 1988. Effects of grazing management treatment on grassland plant communities and prairie grouse habitat. pp. 58-72 in A. J. Bjugstad, tech. coord., Prairie chickens on the Sheyenne National Grasslands. U.S. For. Serv. and Range Exp. Sta. Gen. Tech. Rep. RM-159. 73pp.

Marcum, C. L., and D. O. Loftsgaarden. 1980. A nonmapping technique for studying habitat preferences. J. Wildl. Manage. 44:963-968.

Marks J. S., and V. S. Marks. 1987a. Habitat selection by Columbian sharp-tailed grouse in west-central Idaho. Department of the Interior, BLM, Boise District, Idaho. 115 pp.

Marshall, W. H. and M. S. Jensen. 1937. Winter and spring studies of the sharp-tailed grouse in Utah. J. Wildl. Manage. 1(3-4):87-98.

MathSoft, Inc. 1994. MathCAD version 5.0 reference manual. MathSoft, Inc., Cambridge, MA. 150 pp.

Mech, L. D. 1983. Handbook of animal radio tracking. Univ. Minnesota Press, Minneapolis. 107 pp.

Meints, D. R. 1991. Seasonal movements, habitat use, and productivity of Columbian sharp-tailed grouse in southeastern Idaho. M.S. Thesis, Univ. of Idaho, Moscow, ID. 74 pp.

Miller, G. C. and W. D. Graul. 1980. Status of sharp-tailed grouse in North America In: Vohs and Knoft (eds.), P. 8-17. 1980. Proc. Prairie Grouse Symp.

Montana Fish and Game Commission. 1993. Hunting and harvest statistics: upland game birds, waterfowl, and turkeys. Montana Dept. of Fish, Wildl. and Parks, Helena, MT. 50 pp.

Nielson, L. S. 1978. The effects of rest-rotation grazing on the distribution of sharp-tailed grouse. M. S. Thesis, Mont. State Univ., Bozeman. 52 pp.

_____., and C. A. Yde. 1982. The effects of rest-rotation grazing on the distribution of sharp-tailed grouse. Pages 147-165 in J. M. Peek and P. D. Dalke, eds. Wildlife-livestock relationships. Dept. Wildl. Res., College of Forestry, Wildl. and Range Sciences, Univ. of Idaho, Moscow.

Nudds, T. D. 1977. Quantifying the vegetative structure of wildlife cover. Wildl. Soc. Bull. 5:113-117.

Oedekoven, O. 1985. Columbian sharp-tailed grouse population distribution and habitat use in south-central Wyoming. M.S. Thesis. Univ. Wyoming, Laramie. 58 pp.

Pepper, G. W. 1972. The ecology of sharp-tailed grouse during spring and summer in the aspen parklands of Saskatchewan. Sask. Dep. Nat. Resour. Wildl. Rep. 1. 56 pp.

Peterle, T. J. 1954. The sharp-tailed grouse in upper peninsula of Michigan. Ph.D. Dissertation. Univ. of Michigan, Ann Arbor. 260 pp.

Rearden, J. D. 1951. Identification of waterfowl nest predators. J. Wildl. Manage. 15(4): 386-395.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert, 1970. Relationships between visual obstruction, measurements and weight of grassland vegetation. J. Range Manage. 23:295-297.

Rotella, J. J., and J. T. Ratti. 1991. Mallard brood movements and wetland selection in southwestern Manitoba. J. Wildl. Manage. 56(3):508-515.

SAS Institute Inc. 1985. SAS user's guide: statistics, version 5 edition. SAS, Inst. Inc., Cary, NC. 956 pp.

Sisson, L. 1976. The sharp-tailed grouse in Nebraska. Nebr. Game and Parks Comm., Lincoln. 88 pp.

StatSoft, Inc. 1994. STATISTICA for windows (Vol. 1): General conventions and statistics I. StatSoft, Inc., Tulsa, OK. 718 pp.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics: a biometrical approach. Second ed. McGraw-Hill Book Co., New York, N.Y. 633 pp.

Symington, D. F. and T. A. Harper. 1957. Sharp-tailed grouse in Saskatchewan. Conserv. Bull. 4, Saskatchewan Dept. National Resources. 24 pp.

Toepfer, J. E., J. A. Newell, and J. Monarch. 1988a. A method for trapping prairie grouse hens on display grounds. Pages 21-23 in A. J. Bjugstad, tech. coord., Prairie chickens on the Sheyenne National Grasslands. U.S. For. Serv. and Range Exp. Sta. Gen. Tech. Rep. RM-159.

U.S. Department of Agriculture. 1988. Range plant handbook. U.S. Dep. of Agr., Forest Service, Washington, DC. 816 pp.

Veseth, R., and C. Montagne. 1980. Geologic parent materials of Montana soils. Mont. Agr. Exp. Sta., Mont. State Univ. and U.S.D.A.-S.C.S. Bull. 721, Bozeman. 117 pp.

Westerskov, K. 1950. Methods for determining the age of game bird eggs. J. Wildl. Manage. 14:56-67.

APPENDIX

TABLES

Table 10. Data summary of sharp-tailed grouse females captured in Nichols Coulee Habitat Unit at the Charles M. Russell NWR, Montana, during 1994-1995.

Hen I.D.	Trap Date	Age	Fate Date	Fate
8.593	04/16/94	J	--	Radio failure, summer 1994.
9.124	04/19/94	A	--	Active at the end of 1995 field season.
8.833	04/19/94	J	--	Killed during winter 1994-1995, mammal.
8.773	04/20/94	A	--	Survived summer 1994, fate unknown.
8.535	04/23/94	J	05/14/94	Killed during pre-nesting period, 1994.
9.065	04/23/94	J	--	Survived summer 1994, fate unknown.
9.044	04/23/94	A	--	Active at the end of 1995 field season.
8.743	04/23/94	A	--	Survived summer 1994, fate unknown.
9.163	04/29/94	A	06/17/94	Killed during nesting period 1994, snake bite.
9.104	04/30/94	A	--	Active at the end of 1995 field season.
8.983	04/30/94	A	06/14/94	Killed during nesting period 1994, avian.
9.005	04/30/94	J	--	Survived summer 1994, fate unknown.
8.863	05/01/94	J	--	Survived summer 1994, fate unknown.
8.713	05/01/94	J	--	Killed during winter 1994-1995, unknown.
9.026	05/03/94	A	--	Active at the end of 1995 field season.

Table 10. (continued)

Hen I.D.	Trap Date	Age	Fate Date	Fate
9.085	05/03/94	A	--	Killed during winter 1994-1995, mammal.
9.262	04/15/95	J		Active at the end of 1995 field season.
9.362	04/15/95	A	--	Active at the end of 1995 field season.
9.221	04/18/95	J	--	Active at the end of 1995 field season.
9.442	04/18/95	J	05/16/95	Killed during nesting period 1995, mammal.
9.383	04/18/95	A	05/16/95	Killed during nesting period 1995, mammal.
9.401	04/18/95	J	05/30/95	Killed during nesting period 1995, unknown.
9.422	04/18/95	J	--	Active at the end of 1995 field season.
9.461	04/18/95	A	05/30/95	Killed during nesting period 1995, unknown.
9.281	04/18/95	J	--	Active at the end of 1995 field season.
9.341	04/19/95	A	--	Lost radio contact 1995, fate unknown.
9.242	04/19/95	A	06/17/95	Killed during nesting period 1995, snake bite.
9.323	04/19/95	A	--	Active at the end of 1995 field season.
9.202	04/19/95	J	--	Active at the end of 1995 field season.

Table 10. (continued)

Hen I.D.	Trap Date	Age	Fate Date	Fate
9.303	04/20/95	A	--	Active at the end of 1995 field season.
9.182	04/20/95	J	--	Active at the end of 1995 field season.
8.981	04/20/95	A	10/10/95	Killed by hunter.
8.681	04/21/95	A	05/24/95	Killed during nesting period 1995, mammal.
8.652	04/21/95	J	--	Active at the end of 1995 field season.
8.563	04/22/95	A	05/25/95	Killed during nesting period 1995, mammal.
8.623	04/22/95	J	--	Active at the end of 1995 field season.
8.983	04/22/95	J	--	Active at the end of 1995 field season.
8.802	04/22/95	A	--	Active at the end of 1995 field season.
8.923	04/22/95	J	05/21/95	Killed during nesting period 1995, mammal.
8.951	04/23/95	J	06/13/95	Killed during nesting period 1995, unknown.
9.085	04/23/95	J	06/09/95	Killed during nesting period 1995, unknown.
8.502	04/23/95	J	05/20/95	Killed during nesting period 1995, mammal.

Table 11. Summary of physical characteristics of sharp-tailed grouse captured in Nichols Coulee Habitat Unit at the Charles M. Russell NWR, Montana, 1994-1995.

	Male				Female			
	adults		yearlings		adults		yearlings	
	avg.	SE	avg.	SE	avg.	SE	avg.	SE
n	44	--	46	--	20	--	22	--
Culmen (mm)	30.6	1.27	30.7	1.09	29.2	1.85	28.8	1.54
Tarsus (mm)	53.6	1.66	53.3	1.57	52.4	1.44	51.2	1.66
Wing chord (cm)	21.8	0.40	21.5	0.42	21.1	0.41	21.0	0.50
Weight (gms)	876	43.7	854	49.6	754	40.4	739	59.6

Table 12. Plant nomenclature by cover type in Nichols Coulee Habitat Unit at the Charles M. Russell NWR, Montana, 1994-1995.

Common Name	Scientific Name
GRASSLAND COMMUNITY	
Grass Type	
Grasses:	
Sandberg Bluegrass	Poa sandbergii
Western Wheatgrass	Agropyron smithii
Prairie Junegrass	Koeleria cristata
Blue Grama	Bouteloua gracilis
Green Needlegrass	Stipa viridula
Japanese Brome	Bromus japonicus
Slender Wheatgrass	Agropyron pauciflorum
Foxtail Barley	Hordeum jubatum
Forbs:	
Sedge	Carex spp.
Yellow Sweet Clover	Melilotus officinalis
American Vetch	Vicia americana
Western Yarrow	Achillea lanulosa
Curlycup Gumweed	Grindelia squarrosa
Spindle Plantain	Plantago spinulosa
Broom Snakeweed	Gutierrezia sarothrae
Field Pennycress	Thlaspi arvense
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Fringed Sagewort	Artemesia frigida
Big Sagebrush	Artemesia tridentata
Silver Sagebrush	Artemesia cana
Black Greasewood	Sarcobatus vermiculatus
Willow	Salix spp.

Table 12. (continued)

Common Name	Scientific Name
Grass/shrub Type	
Grasses:	
Western Wheatgrass	Agropyron smithii
Bluebunch Wheatgrass	Agropyron spicatum
Prairie Junegrass	Koeleria cristata
Blue Grama	Bouteloua gracilis
Green Needlegrass	Stipa viridula
Forbs:	
Sedge	Carex spp.
Yellow Sweet Clover	Melilotus officinalis
American Vetch	Vicia americana
Western Yarrow	Achillea lanulosa
Curlycup Gumweed	Grindelia squarrosa
Spindle Plantain	Plantago spinulosa
Broom Snakeweed	Gutierrezia sarothrae
Common Salsify	Tragopogon dubius
Wild Onion	Allium sp.
Wild Parsley	Mussenion divaricatum
Wild Geranium	Geranium sp.
Prairie Thermopsis	Thermopsis rhombifolia
Silverleaf Scurfpea	Psoralea argophylla
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Big Sagebrush	Artemesia tridentata
Rocky Mountain Juniper	Juniperus scopulorum
Creeping Juniper	Juniperus horizontalis
Prairie Rose	Rosa arkansana
Western Snowberry	Symphorcarpus occidentalis
Skunkbrush Sumac	Rhus trilobata
Fringed Sagewort	Artemesia frigida
Silver Sagebrush	Artemesia cana
Black Greasewood	Sarcobatus vermiculatus
Rubber Rabbitbrush	Chrysothamnus nauseosus
Winterfat	Eurotia lanata

Table 12. (continued)

Common Name	Scientific Name
Grass/forb Type	
Grasses:	
Western Wheatgrass	Agropyron smithii
Bluebunch Wheatgrass	Agropyron spicatum
Prairie Junegrass	Koeleria cristata
Blue Grama	Bouteloua gracilis
Green Needlegrass	Stipa viridula
Forbs:	
Sedge	Carex spp.
Yellow Sweet Clover	Melilotus officinalis
American Vetch	Vicia americana
Western Yarrow	Achillea lanulosa
Curlycup Gumweed	Grindelia squarrosa
Spindle Plantain	Plantago spinulosa
Broom Snakeweed	Gutierrezia sarothrae
Common Salsify	Tragopogon dubius
Wild Onion	Allium sp.
Wild Parsley	Mussenion divaricatum
Wild Geranium	Geranium sp.
Prairie Thermopsis	Thermopsis rhombifolia
Silverleaf Scurfpea	Psoralea argophylla
Pinnate Tansymustard	Descurainia pinnata
Rubberweed	Hymenoxys richardsoni
Scarlet Globemallow	Sphaeralcea coccinea
Small Flowered Wallflower	Erysimum insconspicuum
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Big Sagebrush	Artemesia tridentata
Rocky Mountain Juniper	Juniperus scopulorum
Creeping Juniper	Juniperus horizontalis
Prairie Rose	Rosa arkansana
Western Snowberry	Symphorcarpus occidentalis
Fringed Sagewort	Artemesia frigida

Table 12. (continued)

Common Name	Scientific Name
Forb/grass Type	
Grasses:	
Western Wheatgrass	Agropyron smithii
Bluebunch Wheatgrass	Agropyron spicatum
Prairie Junegrass	Koeleria cristata
Blue Grama	Bouteloua gracilis
Green Needlegrass	Stipa viridula
Forbs:	
Yellow Sweet Clover	Melilotus officinalis
American Vetch	Vicia americana
Pinnate Tansymustard	Descurainia pinnata
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Big Sagebrush	Artemesia tridentata
Rocky Mountain Juniper	Juniperus scopulorum
Creeping Juniper	Juniperus horizontalis
Black Greasewood	Sarcobatus vermiculatus

Table 12. (continued)

Common Name	Scientific Name
SHRUB COMMUNITY	
Shrub/grass Type	
Grasses:	
Western Wheatgrass	Agropyron smithii
Bluebunch Wheatgrass	Agropyron spicatum
Prairie Junegrass	Koeleria cristata
Blue Grama	Bouteloua gracilis
Green Needlegrass	Stipa viridula
Needle and Thread	Stipa comata
Forbs:	
Yellow Sweet Clover	Melilotus officinalis
American Vetch	Vicia americana
Pinnate Tansymustard	Descurainia pinnata
Sedge	Carex spp.
Western Yarrow	Achillea lanulosa
Curlycup Gumweed	Grindelia squarrosa
Broom Snakeweed	Gutierrezia sarothrae
Common Salsify	Tragopogon dubius
Prairie Thermopsis	Thermopsis rhombifolia
Silverleaf Scurfpea	Psoralea argophylla
Pinnate Tansymustard	Descurainia pinnata
Rubberweed	Hymenoxys richardsoni
Purple Prairie Clover	Petalostemum villosum
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Big Sagebrush	Artemesia tridentata
Rocky Mountain Juniper	Juniperus scopulorum
Creeping Juniper	Juniperus horizontalis
Prairie Rose	Rosa arkansana
Western Snowberry	Symphorcarpus occidentalis
Skunkbrush Sumac	Rhus trilobata
Fringed Sagewort	Artemesia frigida
Silver Sagebrush	Artemesia cana
Black Greasewood	Sarcobatus vermiculatus
Rubber Rabbitbrush	Chrysothamnus nauseosus
Chokecherry	Prunus virginianus

Table 12. (continued)

Common Name	Scientific Name
Fringed-Sagewort Type	
Grasses:	
Prairie Junegrass	Koeleria cristata
Blue Grama	Bouteloua gracilis
Western Wheatgrass	Agropyron smithii
Sandberg Bluegrass	Poa sandbergii
Forbs:	
Sedge	Carex spp.
Spindle Plantain	Plantago spinulosa
Broom Snakeweed	Gutierrezia sarothrae
Field Pennycress	Thlaspi arvense
Prairie Pepperweed	Lepidium sp.
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Fringed Sagewort	Artemesia frigida
Big Sagebrush	Artemesia tridentata
Prairie Rose	Rosa arkansana
Winterfat	Eurotia lanata

Table 12. (continued)

Common Name	Scientific Name
Juniper Type	
Grasses:	
Western Wheatgrass	Agropyron smithii
Bluebunch Wheatgrass	Agropyron spicatum
Forbs:	
Western Yarrow	Achillea lanulosa
Common Salsify	Tragopogon dubius
Purple Prairie Clover	Petalostemum villosum
Small Flowered Wallflower	Erysimum insconspicuum
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Rocky Mountain Juniper	Juniperus scopulorum
Creeping Juniper	Juniperus horizontalis
Big Sagebrush	Artemesia tridentata
Woods Rose	Rosa woodsii
Prairie Rose	Rosa arkansana
Western Snowberry	Symphorcarpus occidentalis
Skunkbrush Sumac	Rhus trilobata

Table 12. (continued)

Common Name	Scientific Name
CONIFER COMMUNITY	
Ponderosa-Pine Type	
Grasses:	
Western Wheatgrass	Agropyron smithii
Bluebunch Wheatgrass	Agropyron spicatum
Forbs:	
Sedge	Carex spp.
Yellow Sweet Clover	Melilotus officinalis
American Vetch	Vicia americana
Wild Licorice	Glycyrrhiza lepidota
Prickley Pear Cactus	Opuntia spp.
Shrubs:	
Rocky Mountain Juniper	Juniperus scopulorum
Creeping Juniper	Juniperus horizontalis
Prairie Rose	Rosa arkansana
Western Snowberry	Symphorcarpus occidentalis
Skunkbrush Sumac	Rhus trilobata
Big Sagebrush	Artemesia tridentata

MONTANA STATE UNIVERSITY LIBRARIES
3 1762 10230717 8