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*Original Article*

# Sharp-tailed Grouse in the Nebraska Sandhills Select Residual Cover Patches for Nest Sites

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**ABSTRACT** We evaluated selection and availability of residual cover (dead standing herbage) by sharp-tailed grouse (*Tympanuchus phasianellus*) at time of nest-site selection in an intact and annually grazed grassland. We used radiotelemetry in 1988–1990 to locate 147 nests in the sandhills of Nebraska, USA, and classified 121 as initial nests and 26 as renests. We used visual obstruction readings (VOR) to measure the height and density of residual cover at nests and 373 landscape-scale transects around leks (trap sites). We excluded 77 nests from vegetation analysis because green herbage or early livestock grazing compromised residual cover measurements. Most females selected nest sites with residual cover, mostly warm-season grasses, taller and denser than surrounding vegetation. Visual obstruction readings at 70 nests ($\bar{x} = 7.1$ cm, SE = 0.4, range = 1.0–19.0) averaged almost twice the VOR of residual cover within 12 m of nests ($\bar{x} = 4.0$ cm, SE = 0.3, range = 0.9–11.8) and almost three times the landscape VOR ($\bar{x} = 2.5$ cm, SE = 0.1, range = 0.5–7.9). As further evidence of the importance of residual cover, >52% ($n > 37$) of the females (initial nests) in 1988 and 1989 completed egg-laying and were incubating before green herbage began contributing to nest cover. More than 88% ($n > 42$) of the females relied on residual cover through egg-laying in 1990 when annual drought delayed foliar development. Interested ranchers and land managers can enhance residual cover through livestock grazing management to attract females and presumably increase nest density, a key component of annual sharp-tailed grouse productivity. © 2020 The Wildlife Society.

**KEY WORDS** climate change, livestock grazing, nesting cover, prairie grouse, prescribed fire, rangeland heterogeneity, *Tympanuchus phasianellus*, visual obstruction readings, VOR.

Sharp-tailed grouse (*Tympanuchus phasianellus*) and greater prairie-chicken (*T. cupido*) are highly valued for hunting and ecotourism in the sandhills of Nebraska, USA (Powell 2012). Both species (prairie grouse) are also recognized as flagship species for grassland diversity (Vodehnal and Haufler 2008). A region of approximately 50,000 km$^2$, the Nebraska Sandhills (hereafter referred to as the sandhills) and that portion extending a short distance into South Dakota, USA, is the least-fragmented grassland remaining in the Great Plains and one of the largest sandhill grasslands in the Western Hemisphere (Bleed and Flowerday 1990, Augustine et al. 2019). This expansive grassland of native plant communities supports an economy largely driven by cattle ranching. Grasslands and prairie grouse continue to decline across North America, but with sandy soils limiting development and cultivation, the sandhills will likely become increasingly important for sustaining resilient prairie grouse populations (Whitcomb 1989, Silvy and Hagen 2004, Augustine et al. 2019). There is concern over projected effects of thermal extremes on prairie grouse in the sandhills and range-wide due to climate change (Hovick et al. 2014, Raynor et al. 2018).

Residual cover (dead standing herbage) from the previous growing season is reported as being critical to sharp-tailed grouse that initiate nesting in early spring in the sandhills (Kobriger 1964, Blus and Walker 1966, Sisson 1976). These researchers found most nests in areas with tall and dense residual cover of warm-season grasses and litter, frequently in ungrazed or lightly grazed areas within pastures. Weather and livestock grazing are primary factors affecting nest and brood cover in the sandhills (Sisson 1976, Flanders-Wanner et al. 2004). Viehmeyer (1941) reported on the decimation of prairie grouse populations in the sandhills during the extreme and prolonged drought of the 1930s and attributed the decline to an influx of cattle from surrounding areas and overgrazing of nesting cover.

We were tasked with revising management guidelines for residual nesting cover for sharp-tailed grouse in the sandhills and basing the new guidelines on height and density of residual cover. The original guidelines were developed in the

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1970s to support management of public grasslands in the region and based on mass of residual vegetation. Sisson (1976) published findings of an exhaustive and long-term study of sharp-tailed grouse in the sandhills but his nest vegetation measurements were collected in June and influenced by green herbage. Information was available from nesting studies in tallgrass and mixed-grass prairies in the Great Plains, but we had determined during earlier field studies that height and density measurements from rhizomatous grasslands should not be extrapolated to the bunchgrass plant communities in the sandhills. Focused on residual cover, we designed a study with objectives to 1) measure the height and density of nesting cover at time of nest-site selection, and 2) compare measurements at microhabitat (nest) and macrohabitat (landscape) scales.

## STUDY AREA

We conducted our study in the central sandhills on the Bessey Ranger District of the Nebraska National Forest, Thomas County, Nebraska, during the 1988, 1989, and 1990 nesting seasons (Fig. 1). Dune formation across the sandhills was highly variable (Bleed and Flowerday 1990) with the dunes on the ranger district having relatively high relief (>300 m) and steep slopes up to 60%. Elevation ranged from 840 to 920 m. Annual precipitation at the Valentine National Wildlife Refuge, approximately 87 km north of our study area, averaged 52.5 cm with approximately 65% occurring during the growing season (Apr–Sep). Growing-season precipitation prior to the 1988 and 1989 nesting seasons was 105% and 110% of average, respectively, and 46% (annual drought) of average for the 1990 season.

Our study area was in Major Land Resource Area 65. Ecological sites in the hills (dunes) were sands (online ID code = R065XY033NE) and choppy sands (R065XY034NE), and sandy (R065XY032NE) was the dominant ecological site in the valleys. Detailed descriptions of potential plant communities in each ecological site and transitional pathways between plant communities are available online (USDA Natural Resource Conservation Service 2019*a*). Uresk et al. (2012*a*, *b*) also provide descriptions of grassland plant communities on the ranger district. Vegetation was characteristic of bunchgrass plant communities with little bluestem (*Schizachyrium scoparium*), prairie sandreed (*Calamovilfa longifolia*), sand bluestem (*Andropogon hallii*), sand dropseed (*Sporobolus cryptandrus*), sand lovegrass (*Eragrostis trichodes*), and switchgrass (*Panicum virgatum*) being common warm-season grasses. Needle-and-thread grass (*Hesperostipa comata*) and prairie junegrass (*Koeleria macrantha*) were common cool-season grasses. Blue grama (*Bouteloua gracilis*) and sun sedge (*Carex inops*) were also common. Blowout grass (*Redfieldia flexuosa*) was found mostly in active erosion sites (blowouts). Plant nomenclature follows USDA Natural Resource Conservation Service (2019*b*).

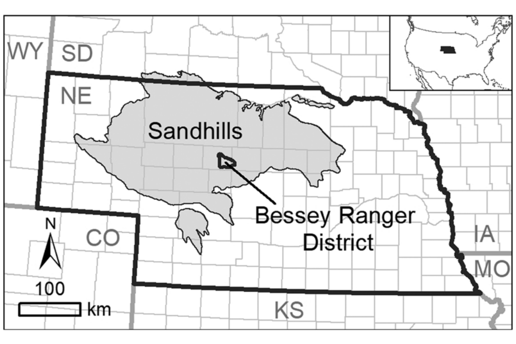


**Figure 1.** The study area was an 11,500-ha area located on the western half of the Bessey Ranger District, Nebraska National Forest, Nebraska, USA, 1988–1990.

Dominant land uses on the ranger district were recreation, primarily prairie grouse viewing and hunting, and livestock grazing. Most of the area was grazed from May into October by domestic cow–calf pairs in 2–5 pasture deferred-rotation grazing systems. Average pasture size was approximately 350 ha. Pastures were stocked at moderate to conservative rates (Holechek et al. 1999), averaging approximately 1 ha/animal unit month. All livestock were privately owned and authorized on the ranger district by federal grazing permits, which made establishing a range of experimental grazing treatments and controls in our study design problematic. A 283-ha research natural area in the study area had not been grazed since the early 1950s.

## METHODS

### Nest Location and Chronology

We used ground searches in March and early April to locate sharp-tailed grouse leks (breeding grounds). We used walk-in traps on leks to capture females (Toepfer et al. 1988), which we fitted with 18-g very-high-frequency radio-transmitters (Wildlife Materials, Carbondale, IL, USA) using poncho and backpack attachments (Brander 1968, Amstrup 1980). We trapped females on 5 leks in 1988, 3 in 1989, and 4 in 1990. We released females at point of capture and monitored their locations and status at 1–2-day intervals with a Telonics TR-2E receiver (Telonics Telemetry-Electronics Consultants, Mesa, AZ, USA) and Yagi antennas. Once telemetry locations during consecutive monitoring days were fixed, we confirmed and marked nest locations. We continued to monitor each nest remotely at least every other day until hatch, abandonment, or predation was suspected. We followed precautionary measures during nest marking over concern of attracting predators.

We recorded lek and nest locations in the field on 1:16,000 color-infrared aerial photographs. We transferred locations to 1:24,000 scale U.S. Geological Survey topographic maps in the laboratory using a Bausch and Lomb (Laval, QC, Canada) zoom-transfer scope. We used an electronic-graphics calculator (digitizer) to measure map distances (to the nearest 100 m) between nests and leks.

We classified the first nest for each female as an initial nest, recognizing that some females may have had ≥1 nest destroyed during early egg-laying. We defined hatch date for successful (≥1 egg hatched) nests as being the first day telemetry triangulation indicated a female was away from her nest and had not returned. We subtracted 23 days from hatch date to estimate incubation initiation date. Assuming females lay 1 egg/day, clutch size was subtracted from incubation initiation date to determine approximate date of nest initiation (first day of egg-laying). To estimate approximate date of nest initiation for failed nests, we subtracted the number of eggs first observed in the nest from date of first nest visit.

We were not required to have our trapping and telemetry protocols reviewed and approved by an Institutional Animal Care and Use Committee at the time of our study. Our protocols were similar to those used more recently by Anderson et al. (2015), and their methods and protocols were reviewed and approved.

### Residual Cover

We used visual obstruction readings (VOR) to measure the height and density of residual cover (Robel et al. 1970, Benkobi et al. 2000, Higgins et al. 2012). We were challenged by a narrow window of opportunity to locate nests and collect VOR measurements before spring plant growth increased or early livestock grazing decreased residual cover measurements. We limited the number of nest measurements to expedite time at nests and minimize effects on females and nest success because most vegetation measurements were made before nest termination. We used a modified Robel pole that was 3 cm in diameter with alternating gray and white bands (Fig. 2). Bands were 2 cm wide with the bottom or first band numbered zero. We recorded number of bands totally obscured by vegetation from a distance of 4 m and height of 1 m as the VOR.

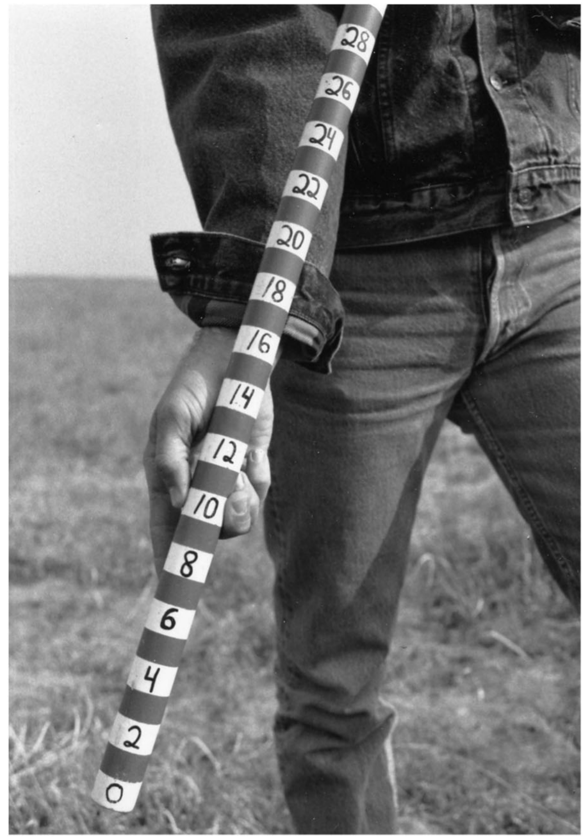


**Figure 2.** A modified Robel pole with 2-cm bands was used to measure the height and density of residual cover at sharp-tailed grouse nests and along landscape-scale transects on the Bessey Ranger District, Nebraska National Forest, Nebraska, USA, 1988–1990. If all or some of the bottom band was visible, the visual obstruction reading was recorded as zero indicating the number of bands totally obscured from view.

For microhabitat assessment, we recorded VOR at each nest site (edge of nest bowl) and 3, 6, 9, and 12 m in the 4 cardinal directions from the nest. We recorded and averaged 2 VOR at each location, each from opposite ends of the same contour as the pole. Limiting measurements to the contour avoided possible visual bias due to the steep slopes in the choppy sands ecological sites. We also recorded dominant plant species (residual and green) contributing to visual obstruction at nests. We made VOR measurements at initial nests 17–23 May each year. We analyzed VOR data with a general linear model repeated measures design and analysis of variance (ANOVA) to account for the relationship between distance readings and dependence between pairs of nests and distance intervals at each replicate (nest site; SPSS 2003). A Levene test for homogeneous variances showed unequal variances among VOR groups (SPSS 2003). When variances were heterogeneous, we used Dunnett's T3 pairwise comparisons test to determine differences for VOR among groups (SPSS 2003). We set $\alpha = 0.05$.

For macrohabitat assessment, we measured VOR of residual cover along 400-m line transects, each with 20 sample stations located at 20-m intervals. We averaged the 20-station means to determine mean transect VOR. As a measure of available nesting cover, we located VOR transects within a 2.2-km radius of the 1988 trap sites (leks). We extended the distance to 2.75 km in 1989 and 1990 to decrease the number of nests occurring beyond our predetermined lek-centric distance. We allocated transect locations around trap sites to hills (sands and choppy sands ecological sites) and valleys (sandy ecological site) following a stratified random sampling design (Cochran 1977, Thompson et al. 1998, Levy and Lemeshow 1999). Sampling intensity averaged approximately 1 transect/30 ha. We oriented transects perpendicular to the predominate slope with a random start, and sampled annually from late March through April. We used ANOVA to test for differences in mean VOR between years, ecological sites, and successful and failed nests. We tested multiple comparisons with least significant differences (Dunnett's T3) and *F*-protected at $\alpha = 0.10$. We used nonhierarchical cluster analysis (Iterative Self-Organizing Data Analysis Technique Algorithm—ISODATA) to identify 3 distinct VOR groupings (Ball and Hall 1967, del Morel 1975). We grouped landscape transects to low, moderate, and high VOR categories (classes). We computed minimum and maximum thresholds for each VOR class using 95% confidence intervals. We split the difference between lower and upper confidence-interval bounds evenly between classes to define the upper and lower bounds of each class.

## RESULTS

### Nest Location and Chronology

We radiotagged 184 females and located 121 nests that we classified as initial attempts. We located an additional

26 renest attempts by previously unsuccessful females. Focusing on initial nests, approximately 90% of the females located their nests within 1.6 km and 2.9 km of the nearest lek and lek of capture, respectively (Table S1 in Supporting Information, available online on the publisher's website). One female left the study area after being fitted with a transmitter and moved 14.5 km from the lek of capture and we considered this distance to be an outlier and excluded it from analysis. Average distance between leks in the study area was $1.7 \pm 0.5$ km (SD; $n = 15$) each year of the study. Nests were located both in the hills and narrow inter-dune valleys. The earliest recorded nest initiation (onset of egg-laying) was 15 April; during the 1988 and 1989 nesting seasons >52% ($n > 66$) of the females (initial nests) completed egg-laying and were incubating when residual vegetation was the only vertical herbaceous cover available (Table 1). Reliance on residual nesting cover during egg-laying increased to >88% ($n > 42$) of the nesting females in 1990 when drought delayed foliar development in the hills by more than a week (Table 1, Data S1 in Supporting Information).

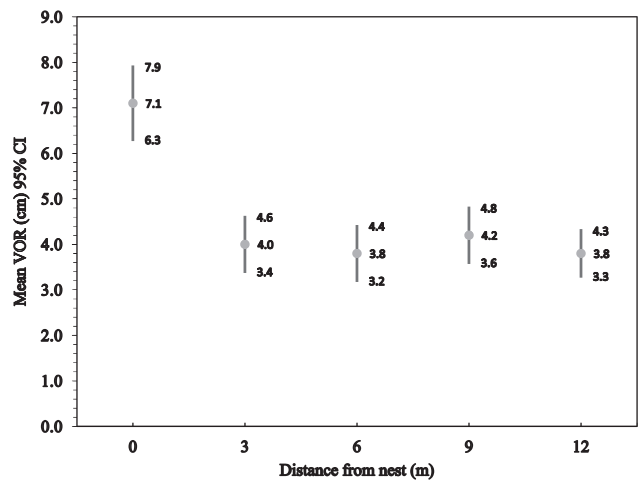


**Figure 3.** Mean visual obstruction readings (VOR; 95% CI) of residual cover at 70 sharp-tailed grouse nests on the Bessey Ranger District, Nebraska National Forest, Nebraska, USA, 1988–1990. These measurements were taken in mid-May and representative of residual cover levels at time of nest-site selection.

### Residual Cover

Most nests were found in or adjacent to tall and dense clumps of residual cover, mostly warm-season grasses. Little bluestem, prairie sandreed, sand bluestem, sand lovegrass, and switchgrass were major contributors to residual cover at nests. Shrubs and subshrubs including chokecherry (*Prunus virginiana*), leadplant (*Amorpha canescens*), New Jersey tea (*Ceanothus americanus*), soapweed (*Yucca glauca*), western sandcherry (*P. pumila*), and Woods' rose (*Rosa woodsii*) also contributed to VOR at many nests. Forbs contributed little to VOR.

We were successful at measuring residual cover at 70 nests before VOR measurements were compromised (Fig. 3; Table S2 in Supporting Information). These measurements were representative of the residual cover levels available at time of nest-site selection. Unfortunately, we had to exclude 77 additional nests from analysis because VOR measurements were compromised. There were no differences among years for mean nest-site VOR ($F_{2,69} = 0.45$, $P = 0.64$) and we pooled annual data. Mean nest-site VOR was $7.1 \pm 0.4$ cm (SE; range = 1.0–19.0), almost twice the mean VOR of $4.0 \pm 0.3$ cm (range = 0.9–11.8) of the residual cover within 12 m of nests (3–12 m; $F_{1,69} = 204.84$, $P \leq 0.001$; Fig. 3). Interestingly, mean nest-site VOR was less than the mean VOR of the secondary cover patch (3–12 m) at 9 nests but the mean VOR of the secondary cover patch at 4 of those nests was relatively high, ranging from 7.3 cm to 9.2 cm. Mean nest-site VOR did not differ between successful ($\bar{x} = 6.4$ cm, SE = 0.7, $n = 19$) and failed nests ($\bar{x} = 7.4$ cm, SE = 0.5, $n = 51$; $F_{1,69} = 4.29$, $P = 0.30$).

Year differences among landscape transects were minimal with the mean VOR in 1988, 1989, and 1990 being 2.6 cm, 2.6 cm, and 2.2 cm, respectively (Table S3 in Supporting Information). With a minimal difference of only 0.4 cm in 1990, we combined the annual data for a 3-year mean VOR of $2.5 \pm 0.1$ cm SE (range = 0.5–7.9). Landscape VOR in the hills ($\bar{x} = 2.5$ cm, SE = 0.1, $n = 335$) and valleys ($\bar{x} = 2.3$ cm, SE = 0.2, $n = 38$) were similar ($F_{1,372} = 1.67$, $P = 0.197$). Mean nest-site VOR (7.1 cm) was almost 3 times greater than the mean landscape VOR ($F_{1,441} = 125.96$, $P \leq 0.001$). The mean VOR (4.0 cm) for the secondary nest patches was almost 2 times greater than mean landscape VOR ($F_{1,441} = 44.74$, $P \leq 0.001$).

**Table 1.** Predicted dates of nest and incubation initiation for sharp-tailed grouse (initial nests) on the Bessey Ranger District, Nebraska National Forest, Nebraska, USA, 1988–1990. Number of nests is shown in parentheses ($n$) and there were missing data for 2 nests in 1988. The 1990 nesting season was preceded by annual drought, which delayed foliar development by more than a week.

| | Cumulative percentage ($n$) | | | |
|---|---|---|---|---|
| | Nest initiation[a] | | Incubation initiation | |
| Date | 1988 and 1989 | 1990 | 1988 and 1989 | 1990 |
| 10 Apr–16 Apr | 1 (1) | | | |
| 17 Apr–23 Apr | 8 (5) | | | |
| 24 Apr–30 Apr | 38 (22) | 35 (17) | | |
| 1 May–7 May | 71 (24) | 81 (22) | 14 (10) | 8 (4) |
| 8 May–14 May | 81 (7) | 92 (5) | 52 (27) | 56 (23) |
| 15 May–21 May[b] | 90 (7) | 98 (3) | 77 (18) | 88 (15) |
| 22 May–28 May[c] | 97 (5) | 100 (1) | 93 (11) | 96 (4) |
| 29 May–4 Jun | 100 (2) | | 94 (1) | 98 (1) |
| 5 Jun–11 Jun | | | 100 (4) | 100 (1) |

[a] First day of egg-laying.
[b] Green herbage began contributing to vertical nest cover in 1988 and 1989.
[c] Green herbage began contributing to vertical nest cover in 1990 (drought).

## DISCUSSION

### Use and Importance of Residual Cover

The importance of residual cover, primarily warm-season grasses, to females was clearly evident given their strong selection for tall and dense residual cover patches at nest sites and their continued and exclusive reliance on residual cover through egg-laying and into early incubation at most initial nests. The heightened value of residual cover during drought was demonstrated in the 1990 nesting season when spring plant growth was delayed and residual cover provided all the vertical herbaceous cover during egg-laying and into incubation at approximately 9 out of every 10 nests.

We would have preferred a wider range of grazing intensities (stocking rates) in our study area, but most if not all nesting females were exposed to a full range of residual cover levels. Our results support those of other researchers that most females in the sandhills select nest sites in taller and denser patches of residual cover (Kobriger 1964, Blus and Walker 1966, Sisson 1976, Prose et al. 2002, Raynor et al. 2018). The residual cover patches at most of our nest sites were surrounded by a secondary patch of residual cover that extended outward from nests ≥12 m, the farthest distance measured in our study. Mean VOR of the secondary cover patches was almost twice the lek-centric landscape VOR. However, we are uncertain if selection was occurring at the secondary-patch scale or if the taller and denser cover patches selected at nest sites simply occurred more often in association with a tall and dense secondary patch. If our study area had been under a lighter grazing intensity (stocking rate) resulting in a higher landscape VOR, we suspect we would have seen less distinction between nest site and secondary patch VOR. Landscape VOR in the research natural area was among the highest in the study area, but females did not disproportionately use the area for nesting. We observed that the long-term absence of cattle grazing in the natural area had apparently resulted in excessive levels of litter accumulation and reduced forb diversity and abundance, when compared with adjoining grazed pastures. These factors may have reduced the value of the natural area for nesting and brooding.

We can only speculate on the natural selection, population fitness, or adaptive context of females selecting for taller and denser residual cover at time of nest-site selection (Cody 1981, Jones 2001). Our finding of similar residual cover levels at successful and failed nests does not appear to support a hypothesis of predator avoidance, but we caution that most of our VOR measurements were collected before nest termination. Predation and nest success results may have been different had vegetation measurements been taken at time of nest termination when most VOR measurements would have been higher as a result of the addition of green herbage to residual cover later in incubation (Data S1 in Supporting Information). Females may be attracted to taller and denser residual cover patches as shelter for more favorable microclimate at nests in the sandhills (Sisson 1976, Raynor et al. 2018). Hovick et al. (2014) found that prairie-chickens in the Flint Hills of Kansas, USA, exhibited strong selection for cooler thermal properties at nests. Raynor et al. (2018) expressed concern that tolerable thermal space for nesting females in the sandhills will likely be reduced under future climate predictions. This is a valid concern given thermal extremes ≥60° C at the soil surface have been reported in the sandhills where vegetative cover was limited or lacking (Pool 1914, Raynor et al. 2018).

Apparently nest and brood cover were available in the study area and across the ranger district at levels that helped support a sustainable sharp-tailed grouse population. Based on long-term (1983–2018) hunter-harvest records for sharp-tailed grouse on the ranger district (M. Nenneman, U.S. Fish and Wildlife Service, and W. Vodehnal, Nebraska Game and Parks Commission, unpublished data), trend in number of birds harvested/hunter-day has been relatively stable for the past 38 years, suggesting a sustainable population (Data S2 in Supporting Information). Livestock grazing management over this period has remained similar with only minor modifications.

## Managing Residual Cover

Managing for residual cover near and around leks is important but we do not recommend limiting management to those areas. Modifying livestock grazing management to enhance residual cover levels in areas currently lacking leks and structural heterogeneity could result in expansion of local sharp-tailed grouse populations and establishment of new leks. Brown (1966) reported establishment of new sharp-tailed grouse leks when cover levels were enhanced in a 260-$km^2$ study area in Montana, USA.

Examining the variability and range (amplitude) of mean station VOR within landscape transects provides information on structural heterogeneity (patchiness). We counted the number and calculated the percentage of individual stations within the landscape transects that had a mean VOR ≥7.1 cm in each of 3 cover classes defined by cluster analysis (Table 2). We selected the mean VOR of

**Table 2.** Mean visual obstruction readings (VOR) of landscape-scale transects ($n = 373$, 1988–1990) were grouped into 3 classes (low, moderate, high) using cluster analysis (Iterative Self-Organizing Data Analysis Technique Algorithm—ISODATA). The number and percentage of individual stations with a VOR ≥7.1 cm provide a measure of the availability of suitable nesting cover (nest site) in each VOR class for sharp-tailed grouse. Study area was on the Bessey Ranger District, Nebraska National Forest, Nebraska, USA.

| VOR class | No. of transects | Mean transect VOR (cm) | VOR class range[a] | No. of stations[b] | No. of stations with mean VOR ≥7.1 cm[c] |
|---|---|---|---|---|---|
| Low | 221 | 1.7 | ≤2.4 | 4,420 | 106 (2%) |
| Moderate | 130 | 3.2 | 2.5–4.4 | 2,600 | 280 (11%) |
| High | 22 | 5.6 | ≥4.5 | 440 | 150 (35%) |

[a] Mean transect VOR classes based on 95% CIs.
[b] 20 stations/transect.
[c] 7.1-cm value is the mean VOR at 70 nest sites in the study area.

our 70 nests (7.1 cm) as the best and least subjective descriptor of suitable (not minimum) nest-site cover. Results of this analysis illustrate the scarcity of available and suitable nest-site patches in the low VOR class and increasing availability in the moderate and high VOR classes (Table 2). Based on these results and our field observations, we suggest the scarcity of available nest-site patches would limit sharp-tailed grouse production in areas where the low VOR class is a dominant landscape feature. We are uncertain if availability of nest cover is a limiting resource for females in the moderate VOR areas. We caution that in this study we recorded the total number of bands obscured from vision as the VOR, and this is a modification from the last band (or mark) visible technique originally described by Robel et al. (1970). Had we followed the last-band-visible technique, VOR values in Table 2 would have increased by 2 cm each.

Range management practices that promote structural heterogeneity increase availability of the taller and denser patches of residual cover selected by nesting females. By maintaining or promoting uneven livestock distribution, more areas within pastures remain lightly grazed, thereby providing a more diverse cover mosaic (Sisson 1976). This is contrary to traditional range management that advocates uniform forage utilization by livestock (Krausman et al. 2009, Fuhlendorf et al. 2017). Ranchers and land managers can consult several publications, most online, for more detailed information on grazing management options for enhancing structural heterogeneity for prairie grouse and other grassland birds (Reece et al. 2001, 2008; Toombs et al. 2010, Schacht et al. 2011, Powell et al. 2014). Sliwinski et al. (2020) cautioned that changing grazing systems without other modifications may only result in limited enhancement of structural heterogeneity in the sandhills. Harrison et al. (2017) recommended managing for structural heterogeneity both in and between pastures for nesting prairie-chicken in the sandhills and we recommend the same for sharp-tailed grouse. Management options for enhancing structural heterogeneity within individual pastures can become substantially reduced when pastures are cross-fenced into smaller units to facilitate more uniform and high-intensity grazing (Sisson 1976).

A key strategy in residual cover management is drought planning to facilitate operational flexibility needed by ranchers for timely adjustment in livestock numbers at onset of drought. When drought delays and reduces new plant growth, nesting females (and broods) must increasingly rely on residual cover for concealment and thermal protection (Flanders-Wanner et al. 2004). In addition to helping mitigate effects on residual cover and prairie grouse, drought management planning and implementation helps expedite recovery of grasslands after drought. Gates et al. (2003) listed 5 vital functions of residual cover in grassland recovery from drought: soil cover, wind barrier, nutrient pool, snow capture, and feed reserve. There are several publications that can be consulted for effective drought management planning (Reece et al. 1991, Gates et al. 2003, Kachergis et al. 2014).

Prescribed fire is used to achieve a variety of grassland objectives in the sandhills and critically important for controlling and removing eastern redcedar (*Juniperus virginiana*) invasion. Sliwinski et al. (2020) also suggests prescribed fire for enhancing structural heterogeneity for grassland birds in the sandhills. Although prescribed fire is an effective grassland management tool, we suggest there are some additional prairie grouse considerations when planning large landscape-scale prescribed burns. Our study results combined with those of other researchers demonstrate the importance of both litter and residual cover to nesting prairie grouse and their broods in the sandhills (Sisson 1976, Anderson et al. 2015, Harrison et al. 2017, Raynor et al. 2018). Litter also has important ecological functions in semiarid grasslands, especially in the sandhills (Whitcomb 1989, Molinar et al. 2001, Mangan et al. 2004). We recommend assessing potential short- and long-term effects of prescribed fire on prairie grouse populations (i.e., monitoring lek density and attendance) and the seasonal availability of residual nesting cover, litter, and shade in the vicinity of leks.

## MANAGEMENT IMPLICATIONS

Our study results demonstrate the importance of providing taller and denser patches of residual cover in April or early May in the sandhills to attract females and presumably increase nest density, a key component of annual sharp-tailed grouse productivity. We recommend managing for the moderate or high VOR class (Table 2) in pastures or targeted areas. We caution that this guideline may be unattainable in the western sandhills that are drier and less productive than our study area. As a basis for further refinement of management guidelines, we suggest additional field experiments to evaluate cause-and-effect relationships between structural heterogeneity, timing of prescribed fire, timing of livestock grazing, grazing intensity (stocking rate), and prairie grouse vital rates. Predicted threats of climate change in the form of more frequent and prolonged drought and hotter temperatures elevate the importance of residual cover management in ameliorating effects on prairie grouse (Mangan et al. 2004, Hovick et al. 2014, Raynor et al. 2018).

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## SUPPORTING INFORMATION

The online version of this report on the publisher's website provides additional information on sharp-tailed grouse nests and residual cover.