EFFECTS OF LIVESTOCK GRAZING MANAGEMENT ON THE ECOLOGY OF SHARP-TAILED GROUSE, GRASSLAND BIRDS, AND THEIR PREDATORS IN NORTHERN MIXED GRASS PRAIRIE HABITATS

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2018 3rd QUARTER REPORT

Submitted by:

Wildlife Habitat Ecology Lab
Department of Animal & Range Sciences
Montana State University

Presented to:

Montana Department of Fish, Wildlife, and Parks

Principal Investigators

Lance McNew
Lorelle Berkeley
Melissa Foster
John Ensign

Graduate Students

Megan Milligan

Field Technicians

Trenton Heisel, Julie Herrick, Lara Macon, Matt Williams

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3rd Quarter Report
Reporting Period: 1 July – 30 September

EXECUTIVE SUMMARY

Field efforts this quarter focused on tracking and locating nests of radio-marked female sharp-tailed grouse, conducting habitat surveys at nest and brood locations as well as random points throughout the study area, analyzing nest survival and space use data and deploying remote cameras to evaluate predator occupancy. Results from the first objective were presented at the 14th International Grouse Symposium in September.

Sixty-four radio-marked females (52 captured in 2018, 12 captured in 2017) were monitored ≥ 3 times per week throughout the nesting and brood-rearing period. Females initiated 62 nests (53 first nests, 9 renests). Nesting frequency (± SE) was 0.97 ± 0.02, while the probability of renesting after first nest failure was 0.60 ± 0.12. Thirty-eight nests successfully hatched and 24 failed (22 depredated, 1 abandoned, 1 trampled by cattle). Of the successful nests, 6 were located on the easement and 32 on reference areas of the study site. The best predictors of nest site selection included visual obstruction (VOR) at the nest bowl, percent residual grass cover and shrub cover, and percent new grass cover and a measure of fragmentation (mean shape complexity). All variables were positively related to the relative probability of selection, with the exception of new grass cover and fragmentation, which were negatively related. Overall nest survival varied by year and was 0.48 ± 0.07 in 2018 (ranged from 0.29 ± 0.06 in 2016 to 0.48 ± 0.07 in 2018). The best predictors of nest survival were year, VOR, the proportion grassland and percent forb cover, which were all, with the exception of forb cover, positively related to survival. We did not find evidence of a grazing system effect on nest survival.

We monitored 38 broods to estimate survival and document habitat use. Six broods spent the majority of the time (>60% of brood locations) on the easement, 29 spent the majority of time in the reference area, and 3 split time between the two areas. Brood success, calculated as the proportion of broods fledging ≥1 chick to 14-d of age, was 0.67 ± 0.19, 0.72 ± 0.08, and 1.0 for broods located on the easement, reference, and both areas, respectively. Of broods that survived to fledging, the proportion of chicks that survived was 0.54 ± 0.17, 0.63 ± 0.07, and 0.62 ± 0.15 for broods located on the easement, reference, and both areas, respectively.

We determined that 28 radio-marked females were killed by predators: 15 and 8 by mammalian and avian predators, respectively, and 5 by an unknown predator. An additional 2 females were harvested by hunters. One female was right censored from the study when the transmitter was found with no sign of death. An additional 4 females left the study area within 2 weeks of capture and were right censored after they could not be relocated for more than 2 months. Two

females have moved onto land to which we do not have access and so were monitored solely for survival.

During this quarter, we collected a total of 761 locations from 50 females. During the 2018 breeding season (April – August), 44 females had ≥30 unique locations. Mean breeding season home range size for all females in 2018 was 435 ± 401 ha, but varied from 57 ha to 2,260 ha. Females showed strong preference for mixed grass prairie habitats over other non-grassland habitats (e.g., cultivation) but exhibited conflicting selection with regards to grazing variables. Distance to grassland edge was the best predictor of home range size and was negatively related to the size of female home ranges during the breeding season ($\beta = -1.43 \pm 0.75$).

OBJECTIVES

Objective 1: Investigate rest rotation grazing as a rangeland management technique to improve sharp-tailed grouse fecundity and survival.

Accomplishments Since Last Quarter:

Methods.– Efforts this quarter focused on intensive monitoring of radio-marked females to locate nests and broods. Fifty-seven females were fitted with transmitters in the spring and an additional 13 females that were radio-marked during the 2017 field season were still present in the study area and therefore monitored for a second year (see previous quarterly report). Three females left the study area within 2 weeks of capture and three died within a week of capture, so 64 females were regularly monitored during the 2018 season.

Radio-marked females were located by triangulation or homing ≥3 times/week using portable radio receivers and handheld Yagi antennas during the nesting and brood-rearing period (April—June). When females localized in an area and their estimated location did not change for 2 successive visits, we assumed that the female was sitting on a nest. For half of the females, we used portable radio receivers and handheld Yagi antennas to locate and flush the female so eggs could be counted and nest location recorded with a handheld GPS unit. We marked nest locations with natural landmarks at a distance ≥ 25 m to aid in relocation. Nest sites were not visited again until it was determined that the female had departed (i.e., was located away from the nest for ≥ 2 days during incubation and ≥ 1 day after expected hatch date) due to successful hatching of the clutch or failure due to either predation or abandonment. Nesting females were otherwise monitored by triangulation from a distance > 25 m. Thus, nest sites for half of the females were only disturbed by the presence of an observer a maximum of 1 time during the laying and incubation period. The remaining half of the females were never flushed and nest attempts were monitored from a distance of >25 m to evaluate whether the protocol of flushing females has a negative effect on nest survival. A female was assumed to be incubating if she was located in the same location for 2 consecutive visits and nest sites were only visited after the female was located away from the nest for ≥ 2 days during incubation or ≥ 1 day after expected hatch date.

Once the female departed the nest, we classified nest fate as successful (≥ 1 chick produced), failed, depredated, or abandoned. Nests were considered abandoned if eggs were cold and unattended for >5 days. Nests were considered failed if the eggs were destroyed by flooding, trampling by livestock, or construction equipment. Nests were considered depredated if the entire clutch disappeared before the expected date of hatching, or if eggshell and nest remains indicated that the eggs were destroyed by a predator. When a depredation event occurred, the egg remains were evaluated and the area was searched for predator sign. For successful nests, hatchability was calculated as the percentage of eggs that hatched and produced chicks. Eggs that failed to hatch were opened to determine stage of development and possible timing of embryo failure.

Successful broods were relocated ≥3 times/week until failure. Pre-fledging brood survival was estimated by conducting flush counts between 14 and 16 days post hatch. Flush counts were conducted at dawn when chicks were close to radio-marked females to determine the number of surviving chicks in the brood. After females were flushed, the area was systematically searched and the behavior of the female observed to assess whether chicks were present but undetected. For counts of 0 chicks, the brood female was flushed again the following day to be certain no chicks remained in the brood. Broods were considered successful if ≥ 1 chick survived until fledging at 14-d post-hatch (Pitman et al. 2006). Flush counts were repeated at 14, 30, 45, and 60 days post-hatch or until we were confident that no chicks remained with the female.

We monitored radio-marked females ≥3 times per week to estimate survival. Transmitters were equipped with a mortality switch that activated after 6–8 hours of inactivity. Once the mortality switch activated, transmitters were located, and the area searched to determine probable cause of death. Mortality events were classified as either predation, hunter, other, or unknown. Predation mortalities were further identified as either mammal, avian, or unknown predator. A mortality event was classified as mammalian predation if bite marks, chewed feathers, or mammalian tracks were present. Mortality was determined to be avian predation if the carcass had been decapitated and/or cleaned of the breast muscle with no bite marks, or if the feathers had been plucked. If there were conflicting signs of mortality, the event was classified as unknown predation. Females were censored from the study if their collars were found with no sign of death or if they could not be located for ≥2 months.

We evaluated habitat conditions at each nest and brood flush site within 3 days of hatching/flushing or expected hatch date in the case of nest failure (Figure 1). We recorded visual obstruction readings (VOR) at the nest bowl and at four points 6 m from the nest in each cardinal direction. At each point, VOR was measured in each cardinal direction from a distance of 2 m and a height of 0.5 m using a Robel pole (Robel et al. 1970). We estimated non-overlapping vegetation cover (percent new grass, residual grass, forbs, shrubs, bare ground, and litter) at 12 subsampling locations within 6 m of the nest using a 20 x 50 cm sampling frame (Daubenmire 1959). At each subsampling plot, we measured the heights of new grass, residual grass, forbs, shrubs and litter. We also estimated shrub cover using the line-intercept method, recording the species, height, and length of each shrub intersecting the transect. For nests, we conducted parallel sampling at randomly selected points within a study area defined by a minimum convex polygon placed around the leks of capture and buffered to 2 km. For broods, we conducted parallel sampling at paired points in a randomly determined direction and distance (maximum of 250 m) from each flush location to represent available habitat within the average daily distance traveled by broods (Goddard et al. 2009). Random points that fell within unsuitable habitat (i.e., water, cultivation, etc.) or were located on properties to which we did not have access were replaced.

We also measured nest habitat at the home range scale (500 ha, based on estimated home range sizes of sharp-tailed grouse during the breeding season, see below) under the assumption that the home range contained the resources utilized by a female during the nesting season. The home range area was defined as a circular plot with a 1,300 m radius centered on each nest and random location. We calculated habitat variables at the home range scale using remotely sensed data and ArcMap 10.4. We included road datasets for both Montana and North Dakota and calculated the density of paved and gravel roads within each home range (Montana State Library, North Dakota GIS Hub Data Portal). Paved roads, including state highways, had higher traffic volumes and were assumed to represent a different level of disturbance than gravel roads. We also included the locations of oil pads which represented another form of disturbance in the study area and calculated the distance to the nearest oil pad from the center of each home range. Landcover analyses utilized the 30 m resolution LANDFIRE data depicting vegetation type (LANDFIRE 2013). We measured the distance from the center of each home range to the nearest patch of non-grassland habitat. In addition, we used the Patch Analyst Extension in ArcMap to calculate the proportion of grassland, the density of edge habitat, and grassland shape complexity.

We collected stocking information for every pasture in which radio-marked sharp-tailed grouse were located. For each pasture, we recorded the type of animal (cow/calf pairs, heifers, bulls, or horses), number of head, and the dates when animals were in the pasture. This allowed us to calculate the following grazing management variables: grazing system (rest-rotation, summer rotation, season-long), stocking rate (AUM ha^{-1}), stocking intensity (AU ha^{-1}), stocking duration (in months), and season of stocking (growing season [May—July], post-growing season [August—November], season-long [May—November], or rest [no grazing for entire year]).

Nesting frequency was calculated as the percentage of females that attempted a nest. The probability of renesting was calculated as the number of observed renesting attempts divided by the number of unsuccessful first nests minus the number of females that had first nests but were unavailable to renest. A female was considered unavailable if she was killed during the first nest attempt or could not be located after first nest failure.

We examined habitat variables influencing nest site selection at multiple spatial scales using resource selection functions. Nest were considered used sites and, as we did not conduct searches for nests of unmarked grouse, random points were considered available following sampling protocol B of Manly et al. (2002). Therefore, we used resource selection functions to compare habitat variables at used sites (1) and available sites (0). Habitat variables at each spatial scale are described above. We built sets of candidate models at each spatial scale and across all scales in Program R with female ID as a random effect to account for potential autocorrelation among nests. Models were compared using AIC_c and model selection was based on minimization of AIC_c and AIC_c weights (w_i). Underlying variables represented factors that were not of primary interest from a habitat or management perspective and included year, hen age, and nest attempt. Variables considered at the nest level included VOR at the nest bowl and averaged within the 6 m radius plot, distance to grassland edge, and the percentage of shrubs, new grass, residual grass, forbs, and bare ground. Different functional relationships with VOR were examined, including linear, exponential and natural log models (i.e., pseudo-threshold effects; Dugger et al. 2005, McNew et al. 2014). Variables considered at the home range level included the proportion of grassland habitat, density of edge habitat, grassland shape complexity, and distance to either oil pad or lek. The density of either gravel or paved roads was ≥ 0 for only a small portion of nests and so neither variable was included in analyses.

Nest success is the proportion of nests that produce ≥1 chick, whereas nest survival accounts for potential losses of nests before discovery. We constructed nest survival models using the RMARK package in Program R to calculate maximum likelihood estimates of daily nest survival and evaluate the effects of habitat conditions on daily nest survival during a 77-d nesting period during 28 April – 12 July (White and Burnham 1999, Dinsmore et al. 2002). Before fitting models, we examined correlations for each pair of variables and if a pair was highly correlated ($r \geq 0.5$, $p < 0.05$), we used single-factor models to determine which of the two variables accounted for the largest proportion of variation in daily nest survival. We considered the variable with the lowest model deviance to be the primary variable to consider in subsequent analyses.

We developed a candidate set of models representing hypotheses regarding the effects of grazing management and local and home-range scale habitat conditions. Models were compared using Akaike's Information Criterion adjusted for small sample sizes (AIC_c) and models with large model weights (w_i) and AIC_c values ≤ 2 from the best-fit model were considered equally parsimonious (Burnham et al. 2011). We first assessed underlying effects models including variables of nest attempt, female age, female condition, flushing effect, daily temperature, and three precipitation variables compared to a null model of constant daily nest survival (Goddard and Dawson 2009). Female condition was calculated by regressing body mass against the length of the wing chord using the reduced major axis method (Green 2001). Precipitation variables included daily precipitation with a 1-day time lag, growing season precipitation from the previous year (total precipitation from previous April to June), and available precipitation from that year (total precipitation from October to May). We also included and evaluated the effect of Year (2016, 2017, 2018) to account for any annual variation in nest survival not addressed by our other measures. We then selected the most parsimonious models at each of the different spatial scales (nest- and home range level) and assessed them in the final candidate model set with important grazing variables. The stocking rate during the previous year's grazing season rather than the current year was used, because the majority of first nests were initiated prior to pastures being stocked. Variables considered at the nest level included VOR at the nest bowl and averaged within the 6 m radius plot, distance to grassland edge, and the percentage of shrubs, new grass, residual grass, forbs, and bare ground. Different functional relationships with VOR were examined, including linear, exponential and natural log models (i.e., pseudo-threshold effects; Dugger et al. 2005, McNew et al. 2014). Variables considered at the home range level included the proportion of grassland habitat, density of edge habitat, grassland shape complexity, and distance to oil pad. The density of either gravel or paved roads was ≥ 0 for only a small portion of nests and so neither variable was included in analyses. Finally, we developed a separate set of candidate models to examine the effects of grazing variables on nests within the rest-rotation pastures (*n*=57) and evaluate effects on nest survival of the different treatments within the system (grazed during the growing season, grazed post-growing season, rested entire year).

Overall nest survival for precocial species is the probability that a nest will survive the entire nesting period, defined as the mean laying plus incubation interval for grouse at our study sites (37-d). Variance of overall nest survival was estimated with the delta approximation (Powell 2007). The average duration of the incubation period (27-d) was determined from observations of our sample of successful nests and from previous work (Connelly et al. 1998).

Initial brood size was determined by the number of chicks that were known to hatch based on nest observations. Brood success was calculated as the proportion of broods that successfully fledged ≥1 chick. Fledging success was calculated as the proportion of chicks that survived until fledging among successful broods. Broods were included in the easement category if >60% of brood locations were within the easement boundaries, in the reference category if >60% of locations were in the reference area, and in the category "both" if they split their time between the two areas.

Results.– Sixty-four radio-marked females were monitored regularly throughout the 2018 breeding season. Females initiated 62 nests (53 first nests, 9 renests; Figure 2, Table 1). Nine females died or were censored from the study before initiating a nest (see below for full mortality results). Median nest initiation date for all nests was 7 May (5 May for first nests, 4 June for renests; range: 28 April – 12 June). Nesting frequency (± SE) was 0.97 ± 0.02 (nests were not located for two females), while the probability of renesting after first nest failure was 0.60 ± 0.12. Thirty-eight nests successfully hatched and 24 failed (22 depredated, 1 abandoned, 1 trampled by cattle; Table 1). Hatch rate of eggs (± SE) for first nests and renests was 91.4 ± 2.4% and 95.6 ± 2.5%, respectively. Mean clutch size for all nest attempts was 10.2 ± 0.59 eggs. Mean clutch size for first nest and renests was 10.3 ± 0.69 and 9.7 ± 0.60 eggs, respectively.

With regards to nest site selection, none of the underlying variables, including year, female age and nest attempt, improved model fit over the null model (Table 2). Preliminary analyses suggested that visual obstruction at the nest bowl best predicted nest site selection and that a pseudo-threshold model best represented the relationship between visual obstruction and nest site selection, so only models with the natural log transformation of nest VOR were included in analyses. At the nest-level, nest site selection was best predicted by VOR at the nest bowl and the percentage of new grass, residual grass, and shrubs ($\Delta AIC_c = 0$, $w_i = 0.61$, Table 3). At the home-range level, the model containing a measure of fragmentation (mean shape complexity or MSI) received the most support ($\Delta AIC_c = 0$, $w_i = 0.58$, Table 4). Of the grazing variables, a combination of stocking rate and the timing of grazing best predicted nest site selection ($\Delta AIC_c = 0$, $w_i = 0.70$, Table 5). In the final candidate model set, the model that included all habitat variables at both the nest and home-range level received the most support ($\Delta AIC_c = 0$, $w_i = 0.88$, Table 6). Confidence intervals for VOR, MSI, and proportion residual grass and shrubs did not overlap zero (Figure 3), suggesting significant effects. The probability of nest site selection increased with residual grass cover (Figure 4), shrub cover (Figure 5), and with VOR at the nest bowl up to a threshold (Figure 6), and decreased with increasing fragmentation or MSI (Figure 7). Models with grazing management effects were not supported (Table 6).

Overall nest survival varied by year and was 0.48 ± 0.07 in 2018 (ranged from 0.29 ± 0.06 in 2016 to 0.48 ± 0.07 in 2018). The underlying-effects model that best predicted nest survival included nest year ($\Delta AIC_c = 0$, $w_i = 0.71$, Table 7). Preliminary analyses suggested that visual obstruction averaged across the 6 m radius plot best predicted nest survival and that a pseudo-threshold model best represented the relationship between visual obstruction and nest survival, so only models with the natural log transformation of average VOR were included in analyses. At the nest-level, VOR was in the top four models, accounting for 91% of model weight (Table 8). Percentage forb, residual grass, and new grass each received some support in combination with VOR ($\Delta AIC_c = 0.50 – 1.83$, $w_i = 0.13 – 0.26$) and so were examined in the final model set. At the home-range level, proportion grassland marginally improved model fit compared to the null model ($\Delta AIC_c = 0$, $w_i = 0.27$, Table 9). None of the grazing variables improved model fit over the null model (Table 10), but models including grazing system and stocking rate were included in the final model set for comparison. In the final candidate model set, the model that included both nest year, VOR, the percentage forbs and the proportion grassland received the most support ($\Delta AIC_c = 0$, $w_i = 0.47$, Table 11). Confidence intervals for year, VOR and proportion grassland did not overlap zero (Figure 8), suggesting significant effects. Nest survival increased each year from 2016 to 2018 and increased with proportion grassland (Figure 9) and VOR up to a threshold, as represented by the pseudo-threshold model (Figure 10). Models with grazing system effects were not supported (Figure 11, Table 11). Measured vegetation variables did not differ between the three grazing treatments (Figure 12), which may explain a lack of a system-level effect. Furthermore, there was no evidence for an effect of treatment on nest survival within the rest-rotation system (Table 12). While there were differences in percent new and residual grass cover between the treatments, visual obstruction was the strongest predictor of nest survival and VOR did not differ between the treatments (Figure 13).

We monitored 38 broods to estimate survival and document habitat use (Table 13). Six broods spent the majority of the time (>60% of brood locations) on the easement, 29 spent the majority of time in the reference area, and 3 split time between the two areas. Brood success, calculated as the proportion of broods fledging ≥1 chick to 14-d of age, was 0.67 ± 0.19, 0.72 ± 0.08, and 1.0 for broods located on the easement, reference, and both areas, respectively. Of broods that survived to fledging, the proportion of chicks that survived was 0.54 ± 0.17, 0.63 ± 0.07, and 0.62 ± 0.15 for broods located on the easement, reference, and both areas, respectively.

We determined that 28 females were killed by predators: 15 and 8 by mammalian and avian predators, respectively, and 5 by an unknown predator. An additional 2 females were hunter mortalities. One female was right censored from the study when the transmitters was found with no sign of death. An additional 4 females left the study area within 2 weeks of captured and were right censored after they could not be relocated for more than 2 months. Two females have moved onto land to which we do not have access and so were monitored solely for survival.

Goals For Next Quarter:

We will continue to monitor radio-marked females ≥1 times/month through the non-breeding season (Sept – March) until death or transmitter failure/loss. In the next quarter, we will focus on finalizing results regarding nesting ecology, including nest survival, nest site selection, and fecundity.

We will use field data to estimate eight demographic parameters related to fecundity for sharp-tailed grouse. Some of these parameters, including clutch sizes (CS_1 and CS_2) and chicks per egg laid (CPE), can be estimated directly from field data. However, other parameters are observed imperfectly. Nests are not observed from the initiation date and nests that fail before discovery must be considered to make population-level inferences. To account for imperfect observation, we will use maximum likelihood estimates of daily nest survival (NSURV) calculated following the methods described above.

Nesting rate (NEST) is calculated as the percentage of females that attempted a nest. The probability of renesting (RENEST) is calculated as the number of observed renesting attempts divided by the number of unsuccessful first nests minus the number of females that had first nests but were unavailable to renest. A hen was considered unavailable if she was killed during the first nest attempt or was not relocated after the failure of a first nest attempt. Initial brood size is determined by the number of chicks that were known to hatch based on nest observations. Brood success (BSURV) is calculated as the proportion of broods that successfully fledged ≥1 chick. Fledging success (FPC) is calculated as the proportion of chicks that survived until fledging among successful broods. Broods are included in the easement category if >60% of brood locations were within the easement boundaries, in the reference category if >60% of locations were in the reference area, and in the category "both" if they split their time between the two areas.

Fecundity (*F*), or the number of female fledglings produced per female, is expressed as a function of these parameters using the following equation:

$$F = \left[(NEST * CS_1 * NSURV_1) + [(1 - NSURV_1) * RENEST * CS_2 * NSURV_2]\right] * CPE * BSURV * FPC * 0.5$$

Bootstrapping procedures will be used to calculate 85% confidence intervals for fecundity estimates by randomly drawing from the underlying distributions of input parameters (McNew et al. 2012).

Objective 2: Investigate impacts of rest-rotation grazing on sharp-tailed grouse home ranges, movements and habitat selection.

Accomplishments Since Last Quarter:

Methods.– Efforts this quarter focused on monitoring female sharp-tailed grouse. Radio-marked females were located via triangulation or homing ≥3 times/week using portable radio receivers and handheld Yagi antennas.

Coordinates for triangulated locations were calculated using Location of a Signal software (LOAS; Ecological Software Solutions LLC, Hegymagas, Hungary) and examined for spatial error. All locations with low estimation precision (>200 m error ellipse) were discarded for initial analysis, but the level of acceptable error will be examined on a case-by-case basis in the future. Previous studies have found that small sample sizes can bias home range estimates (Seaman et al. 1999), so analyses were restricted to birds with ≥ 30 unique locations after excluding multiple relocations of a female at the same nest. We used the fixed kernel method (Worton 1989) with the default smoothing parameter to calculate 95% home ranges for the breeding season (April – August) using the adehabitatHR package in Program R (R Core Team 2014, Vienna, Austria). We also calculated centroids for each home range by estimating the 1% volume contour of each home range and used the geographic center of that contour as the centroid. We then measured distance from each centroid to the nearest lek, grassland patch edge, road and oil pad. We examined second-order habitat selection, or the selection of habitat for an individual's home range within the larger study area, using the adehabitatHS package in Program R and conducted composition analysis of used versus available habitat (Johnson 1980, Aebischer et al. 1993). Available habitat was defined by a 99% fixed kernel home range based on all bird locations in a given year. Habitat classifications utilized the 30 m resolution LANDFIRE data depicting vegetation type (LANDFIRE 2013). Linear models were used to evaluate the effects of year, nest outcome, distance to nearest lek, grassland patch edge, road, and oil pad, and grazing conditions at the home range centroid on home range size.

Results.– During this quarter, we collected a total of 761 locations from 50 females. During the 2018 breeding season (April – August), 44 females had ≥30 unique locations. Mean breeding season home range size for all females in 2018 was 455 ± 401 ha, but varied from 57 ha to 2,260 ha. Breeding season habitat use was ranked as follows: grassland > wooded draws >> other (primarily ruderal grasslands) >> agriculture. (Table 14), suggesting that females did not differentiate between grasslands and wooded draws with regards to preference but selected both habitat types over other habitats, including cultivation. Females strongly selected for mixed grass prairie habitats, even though roughly 83% of the entire study area was composed of mixed grass prairie. Breeding season habitat use in relation to grazing system ranked summer rotation > rest-rotation >> season-long (Table 15), suggesting that females were selecting against pastures grazed season-long when choosing home ranges. Breeding season habitat use in relation to grazing timing was ranked rest > season-long >> growing season > post-growing season (Table 16), suggesting that females were selecting against pastures that were grazed in either the summer or fall and selecting for pastures that were either rested for the entire year or grazed at some point during both the growing and post-growing seasons. Pastures where the timing of grazing was defined as season-long included all pastures that were grazed for >2 weeks during both the growing season (May – July) and post-growing season (August – November) and included pastures with all three system classifications (rest-rotation, summer rotation, season-long), which may explain the conflicting results with regards to season-long pastures. Distance to grassland edge was the best predictor of home range size (Table 17) and was negatively related to the size of breeding season home ranges for females ($\beta = -1.43 \pm 0.75$). There was no evidence for an effect of the grazing system at the centroid of a female's home range on home range size (Figure 14, Table 17).

Goals For Next Quarter:

We will focus efforts in the next quarter on evaluating third-order habitat selection, or habitat selection within the home range, using resource utilization functions (Johnson 1980, Marzluff et al. 2004). RUFs use utilization distributions to quantify the probability of space use and then relate that space use to habitat variables by quantifying use within a defined area (e.g., the home range) as continuous rather than discrete (used vs. unused) and evaluating the entire distribution of an animal's movements rather than the individual sampling points (Marzluff et al. 2004). In addition, RUFs are recommended for use with VHF telemetry data which is subject to measurement error (Hooten et al. 2013). While home ranges provide information on where an individual was located, RUFs can evaluate why particular areas are used more frequently by linking differential space use to habitat variables. To implement RUFs, we will create utilization distributions within 99% fixed kernel utilization distributions using the adehabitatHR package in Program R. We will then evaluate habitat conditions at each grid cell within the polygons using the methods described above. Variables considered will include grazing system, stocking rate, vegetation type, distance to nearest non-grassland habitat, distance to road, and distance to oil pad. The height of the utilization distribution represents the relative amount of use of a given cell, which can then be related to habitat conditions using multiple regression (Marzluff et al. 2004). Using multiple regression, we will estimate coefficients of relative resource use by relating the cell values from the utilization distribution to the habitat variables using the ruf package in Program R. Coefficients represent the degree to which an individual or population utilize resources within the defined home range (Marzluff et al. 2004). Mean standardized coefficients will be used to make population-level inferences about each habitat variable and standardized coefficients with 95% confidence intervals that do not overlap zero will be considered significant. While unstandardized coefficients are necessary to predict expected use, standardized coefficients allow for inferences about the relative influence of habitat variables on animal use and can be used to rank the relative importance of each variable (Marzluff et al. 2004).

Objective 3: Develop a mechanistic understanding of the ecological effects of various grazing treatments with a focus on rest rotation grazing by examining abundance and space use of the grassland bird and mesopredator communities

Project completed. Please see:

Vold, S. T. 2018. Effects of livestock grazing management on the ecology of grassland birds and their predators in a northern mixed-grass prairie ecosystem. Thesis, Montana State University, Bozeman, Montana, USA.

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Table 1. Overview of sharp-tailed grouse nests in pastures managed with different grazing systems in 2018. Egg hatch rate (± SE) is the percentage of eggs that hatched from the initial clutch size. Two nests were in winter-grazed pastures and so were excluded from analysis.

	Median Initiation Date	**Clutch Size**	**First Nests**	**Renests**	**Nests Hatched**	**Median Hatch Date**	**Egg Hatch Rate**
Rest-rotation	10 May	9.3 ± 1.3	12	3	8	15 June	0.98 ± 0.01
Summer rotation	10 May	9.9 ± 0.8	23	6	16	13 June	0.91 ± 0.03
Season-long	5 May	11.4 ± 1.2	16	0	13	13 June	0.89 ± 0.05
Total	9 May	10.2 ± 0.6	51	9	37	3 June	0.92 ± 0.02

Table 2. Support for candidate models predicting sharp-tailed grouse nest site selection based on underlying variables in 2016–18. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and log-likelihoods are reported.

Model	**K**	**AIC_c**	**ΔAIC_c**	**AIC_c w_i**	**Cum. w_i**	**LogLik**
Null	2	528.04	0.00	0.53	0.53	-262.00
Female Age	3	529.90	1.86	0.21	0.73	-261.92
Nest Attempt	3	530.04	2.00	0.19	0.93	-261.99
Year	4	531.96	3.92	0.07	1.00	-261.92

Table 3. Support for candidate models predicting sharp-tailed grouse nest site selection at the nest site level in 2016–18. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and log-likelihoods are reported.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$ w_i**	**Cum. w_i**	**LogLik**
ln(Nest VOR) + %New Grass + %Residual + %Shrub	6	293.20	0.00	0.61	0.61	-140.49
ln(Nest VOR) + %Residual	4	294.22	1.02	0.37	0.98	-143.06
ln(Nest VOR) + %Forb	4	301.41	8.21	0.01	0.99	-146.65
ln(Nest VOR)	3	303.94	10.74	0.00	1.00	-148.94
ln(Nest VOR) + %Shrub	4	304.09	10.89	0.00	1.00	-147.99
ln(Nest VOR) + % New Grass	4	305.88	12.68	0.00	1.00	-148.89
%Bare	3	477.25	184.05	0.00	1.00	-235.59
%New Grass + %Residual + %Shrub	5	483.56	190.36	0.00	1.00	-236.70
%New Grass + %Forb + %Residual + %Shrub	6	485.62	192.42	0.00	1.00	-236.70
%Shrub	3	497.65	204.45	0.00	1.00	-245.79
%Residual	3	521.14	227.94	0.00	1.00	-257.54
Null	2	528.04	234.84	0.00	1.00	-262.00
Dist. to Grassland Edge	3	529.09	235.89	0.00	1.00	-261.51
%Forb	3	529.60	236.40	0.00	1.00	-261.77
%New Grass	3	529.73	236.53	0.00	1.00	-261.83

Table 4. Support for candidate models predicting sharp-tailed grouse nest site selection at the home range level in 2016–18. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and log-likelihoods are reported.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$ w_i**	**Cum. w_i**	**LogLik**
Mean Shape Complexity	3	524.93	0.00	0.58	0.58	-259.43
Null	2	528.04	3.11	0.12	0.71	-262.00
Dist. to Oil Pad	3	528.24	3.32	0.11	0.82	-261.09
Edge Density	3	528.64	3.72	0.09	0.91	-261.29
Prop. Grassland	3	530.03	5.11	0.05	0.95	-261.99
Dist. to Lek	3	530.04	5.11	0.05	1.00	-261.99

Table 5. Support for candidate models predicting sharp-tailed grouse nest site selection based on grazing variables in 2016–18. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and log-likelihoods are reported.

Model	K	AIC_c	ΔAIC_c	AIC_c w_i	Cum. w_i	LogLik
Stocking Rate + Grazing Timing	6	516.16	0.00	0.70	0.70	-251.97
System + Stocking Rate + Grazing Timing	8	518.24	2.07	0.25	0.94	-250.92
System + Stocking Rate	5	523.17	7.00	0.02	0.96	-256.50
Stocking Rate	3	523.33	7.17	0.02	0.98	-258.63
Grazing Timing	5	525.24	9.08	0.01	0.99	-257.54
System x Stocking Rate	7	526.76	10.60	0.00	0.99	-256.23
System + Grazing Timing	7	527.35	11.19	0.00	1.00	-256.52
Null	2	528.04	11.88	0.00	1.00	-262.00
System	4	528.90	12.74	0.00	1.00	-260.40

Table 6. Support for final candidate models predicting sharp-tailed grouse nest site selection in 2016–18. Important variables representing habitat at the nest and home-range level and grazing management are included. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and log-likelihoods are reported.

Model	K	AIC_c	ΔAIC_c	AIC_c w_i	Cum. w_i	LogLik
ln(Nest VOR) + %New Grass + %Residual + %Shrub + Mean Shape Complexity	7	285.97	0.00	0.88	0.88	-135.83
ln(Nest VOR) + %New Grass + %Residual + %Shrub + Mean Shape Complexity + Stocking Rate + Grazing Timing	11	290.53	4.56	0.09	0.97	-133.90
ln(Nest VOR) + %New Grass + %Residual + %Shrub	6	293.20	7.23	0.02	1.00	-140.49
ln(Nest VOR) + %New Grass + %Residual + %Shrub + Stocking Rate + Grazing Timing	10	296.78	10.81	0.00	1.00	-138.09
Stocking Rate + Grazing Timing	6	516.16	230.19	0.00	1.00	-251.97
Mean Shape Complexity + Grazing Timing	7	516.19	230.22	0.00	1.00	-250.94
Mean Shape Complexity	3	524.93	238.96	0.00	1.00	-259.43
Null	2	528.04	242.07	0.00	1.00	-262.00

Table 7. Support for candidate models predicting sharp-tailed grouse nest survival in 2016-18 based on underlying variables. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and deviance are reported.

Model	**K**	**AIC_c**	**ΔAIC_c**	**AIC_c w_i**	**Deviance**
Year	2	753.61	0.00	0.64	749.61
Flush Nest	2	757.84	4.23	0.08	753.84
Growing Season Precip.	2	758.20	4.59	0.07	754.19
Null	1	758.94	5.33	0.04	756.94
Available Precip.	2	759.05	5.44	0.04	755.05
Female Condition	2	759.19	5.58	0.04	755.18
Daily Precip.	2	760.36	6.75	0.02	756.35
Nest Attempt	2	760.56	6.95	0.02	756.56
Female Age	2	760.62	7.01	0.02	756.62
Female Condition + Age	3	761.01	7.40	0.02	755.00
Female Age + Nest Attempt	3	762.20	8.59	0.01	756.19

Table 8. Support for candidate models predicting sharp-tailed grouse nest survival in 2016-18 at the nest site scale. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and deviance are reported.

Model	**K**	**AIC_c**	**ΔAIC_c**	**AIC_c w_i**	**Deviance**
ln(VOR)	2	753.59	0.00	0.33	749.59
ln(VOR) + %Forb	3	754.09	0.50	0.26	748.08
ln(VOR) + %Residual	3	755.41	1.82	0.13	749.41
ln(VOR) + %New Grass	3	755.42	1.83	0.13	749.42
ln(VOR) + %Forb + %New Grass + %Residual	5	757.52	3.93	0.05	747.50
Null	1	758.94	5.35	0.02	756.94
%Forb	2	759.25	5.66	0.02	755.25
%Bare	2	759.58	5.99	0.02	755.58
Dist. to Grassland Edge	2	760.10	6.51	0.01	756.10
%New Grass	2	760.70	7.11	0.01	756.70
%Residual	2	760.94	7.35	0.01	756.94
%Forb + %New Grass + %Residual	4	763.91	10.32	0.00	755.90
%Forb + %New Grass + %Residual + %Shrub	5	764.38	10.79	0.00	754.36

Table 9. Support for candidate models predicting sharp-tailed grouse nest survival in 2016-18 at the home range scale. The number of parameters (K), AICc values, ΔAICc values, model weights (*w*$_i$) and deviance are reported.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$ *w*$_i$**	**Deviance**
Prop. Grassland	2	758.53	0.00	0.27	754.53
Null	1	758.94	0.41	0.22	756.94
Mean Shape Complexity	2	758.99	0.46	0.22	754.98
Edge Density	2	759.23	0.69	0.19	755.22
Dist. to Oil Pad	2	760.60	2.07	0.10	756.60

Table 10. Support for candidate models predicting sharp-tailed grouse nest survival in 2016-18 based on grazing variables. The number of parameters (K), AICc values, ΔAICc values, model weights (*w*$_i$) and deviance are reported.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$ *w*$_i$**	**Deviance**
Null	1	758.94	0.00	0.41	756.94
System	3	760.18	1.23	0.22	754.17
Stocking Rate	2	760.94	2.00	0.15	756.94
System + Stocking Rate	4	762.03	3.09	0.09	754.02
Grazing Timing	4	762.94	4.00	0.06	754.93
Stocking Rate + Grazing Timing	5	764.03	5.09	0.03	754.01
System x Stocking Rate	6	765.08	6.14	0.02	753.06
System + Grazing Timing	6	765.09	6.14	0.02	753.06
System + Stocking Rate + Grazing Timing	7	766.65	7.71	0.01	752.62

Table 11. Support for final candidate models predicting sharp-tailed grouse nest survival in 2016-18. Important variables representing underlying influences, habitat at the nest site and home-range level, and grazing variables are included. The number of parameters (K), AICc values, ΔAICc values, model weights (w_i) and deviance are reported.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$ w_i**	**Deviance**
Year + ln(VOR) + %Forb + Prop. Grassland	6	747.45	0.00	0.47	735.43
Year + ln(VOR) + Prop. Grassland	5	749.05	1.60	0.21	739.03
Year + ln(VOR) + %New Grass + Prop. Grassland	6	750.66	3.21	0.09	738.64
Year + ln(VOR) + %Residual + Prop. Grassland	6	750.92	3.47	0.08	738.90
Year + ln(VOR)	4	753.58	6.13	0.02	745.57
ln(VOR)	2	753.59	6.14	0.02	749.59
Year + ln(VOR) + %Forb	5	754.09	6.63	0.02	744.07
ln(VOR) + %Forb	3	754.09	6.64	0.02	748.08
Year + Prop. Grassland	4	754.18	6.72	0.02	746.17
Year + ln(VOR) + %Residual	5	754.99	7.53	0.01	744.97
ln(VOR) + %Residual	3	755.41	7.96	0.01	749.41
ln(VOR) + %New Grass	3	755.42	7.97	0.01	749.42
Year + ln(VOR) + %New Grass	5	755.47	8.02	0.01	745.45
Year	3	755.61	8.16	0.01	749.61
Prop. Grassland	2	758.53	11.08	0.00	754.53
Null	1	758.94	11.49	0.00	756.94
Grazing System	3	760.18	12.72	0.00	754.17
Stocking Rate	2	760.94	13.49	0.00	756.94

Table 12. Support for candidate models predicting sharp-tailed grouse nest survival in 2016-18 within the rest-rotation system based on grazing variables. The number of parameters (K), AICc values, ΔAICc values, model weights (wi) and deviance are reported. Treatment represents whether a pasture was grazed during the growing season, grazed post-growing season, or rested.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$ w_i**	**Deviance**
Null	1	251.86	0.00	0.61	249.85
Stocking Rate	2	253.72	1.86	0.24	249.70
Treatment	3	255.42	3.57	0.10	249.40
Treatment + Stocking Rate	4	257.43	5.58	0.04	249.39
Treatment x Stocking Rate	6	261.46	9.61	0.01	249.39

Table 13. Sharp-tailed grouse brood survival (± SE) to fledging at 14-d post hatch in the easement and reference sections of the study area in 2018. Brood success is the proportion of broods that successfully fledged ≥1 chick. Fledging rate is the proportion of chicks within broods that survived to fledging at 14 days.

	Number of Broods	**Brood Success**	**Fledging Rate**
Easement	6	0.67 ± 0.19	0.54 ± 0.17
Reference	29	0.72 ± 0.08	0.63 ± 0.07
Both	3	1.0	0.62 ± 0.15
Total	38	0.59 ± 0.08	0.62 ± 0.06

Table 14. Simplified ranking matrix of female sharp-tailed grouse breeding season habitat selection based on vegetation type in 2016-2018. Matrix is based on comparing proportional habitat use within home ranges with proportion of available habitat types. The ‘other’ habitat is composed primarily of ruderal grasslands. Habitat types with the same rank suggest that females did not differentiate between the two categories in habitat selection.

	Grassland	Wooded draws	Other	Agriculture	RANK
Grassland	0	+	+++	+++	1
Wooded draws	-	0	+++	+++	1
Other	---	---	0	+++	3
Agriculture	---	---	---	0	4

Table 15. Simplified ranking matrix of female sharp-tailed grouse breeding season habitat selection based on grazing system in 2016-2018. Matrix is based on comparing proportional habitat use within home ranges with proportion of available habitat types. Grazing systems with the same rank suggest that females did not differentiate between the two categories in habitat selection.

	Summer rotation	Rest-rotation	Season-long	RANK
Summer rotation	0	+	+++	1
Rest-rotation	-	0	+++	1
Season-long	---	---	0	3

Table 16. Simplified ranking matrix of female sharp-tailed grouse breeding season habitat selection based on grazing timing in 2016-2018. Matrix is based on comparing proportional habitat use within home ranges with proportion of available habitat types. Grazing variables with the same rank suggest that females did not differentiate between the two categories in habitat selection.

	Rest	Season-long	Growing Season	Post-growing Season	RANK
Rest	0	+	+++	+	1
Season-long	-	0	+++	+	1
Growing Season	---	---	0	+	3
Post-growing Season	-	-	-	0	3

Table 17. Support for candidate models predicting home range size of female sharp-tailed grouse during the breeding seasons of 2016-2018.

Model	**K**	**AIC$_c$**	**ΔAIC$_c$**	**AIC$_c$ w_i**	**Cum. w_i**	**LogLik**
Dist. to Grassland Edge	3	1903.36	0.00	0.36	0.36	-948.58
Null	2	1904.92	1.56	0.17	0.53	-950.41
Nest Outcome	3	1905.28	1.93	0.14	0.66	-949.54
Year	3	1905.79	2.43	0.11	0.77	-949.80
Dist. to Road	3	1906.67	3.31	0.07	0.84	-950.24
Dist. to Oil Pad	3	1907.01	3.65	0.06	0.90	-950.41
Dist. to Lek	3	1907.02	3.66	0.06	0.96	-950.41
Grazing System	5	1907.57	4.21	0.04	1.00	-948.53

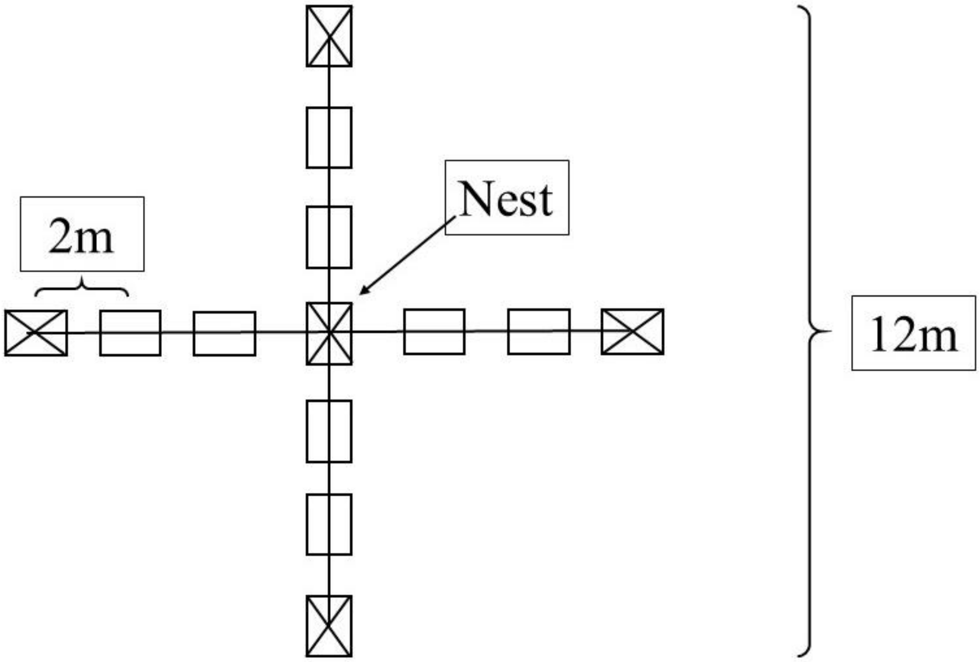

Figure 1. Setup of a vegetation plot. Vegetation cover and height were measured using a Daubenmire frame at each rectangle and visual obstruction with a Robel pole at each X. The lines represent the 12 m transects that were used to estimate shrub cover with the line-intercept method.

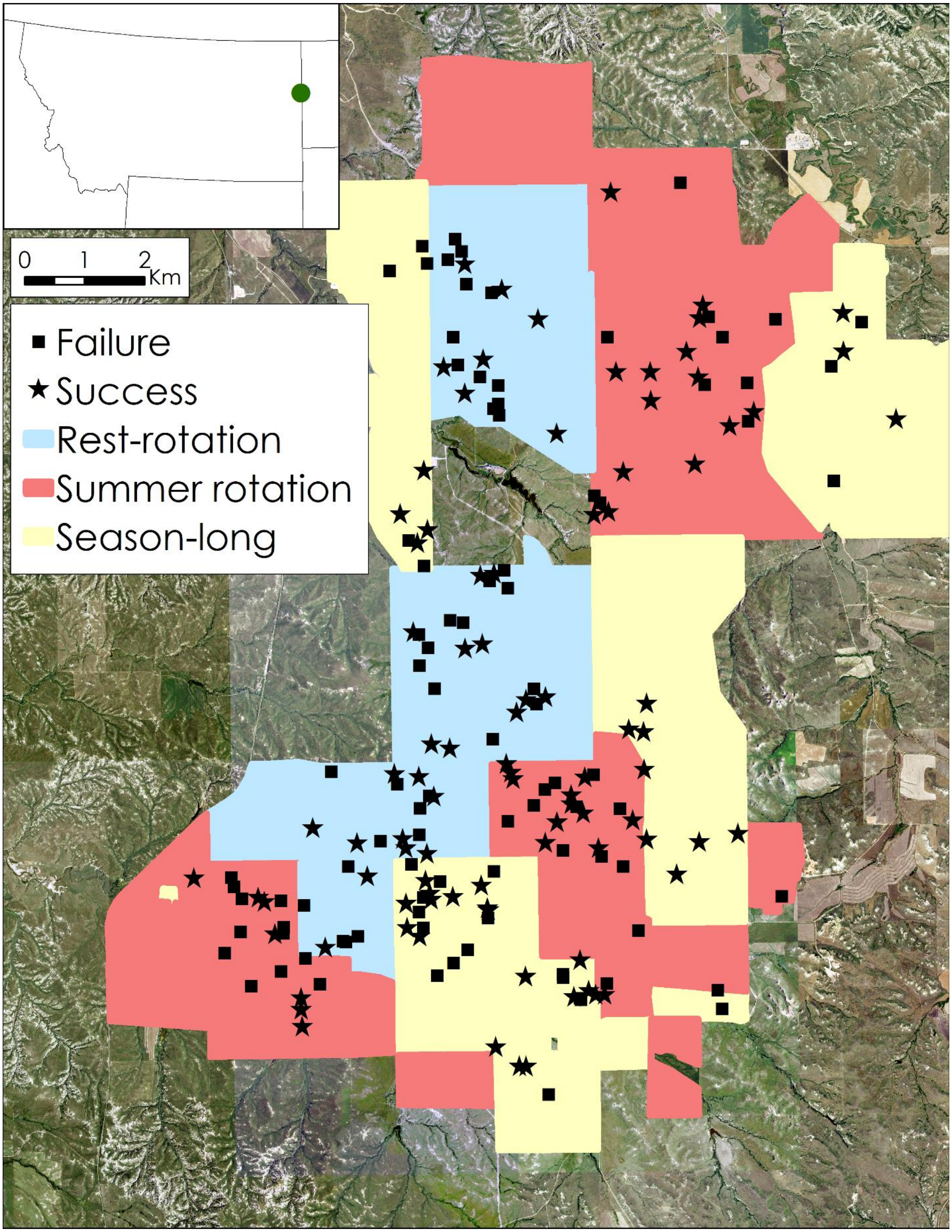

Figure 2. Locations of successful (stars) and failed (squares) sharp-tailed grouse nests in 2016-18 in relation to different grazing treatments.

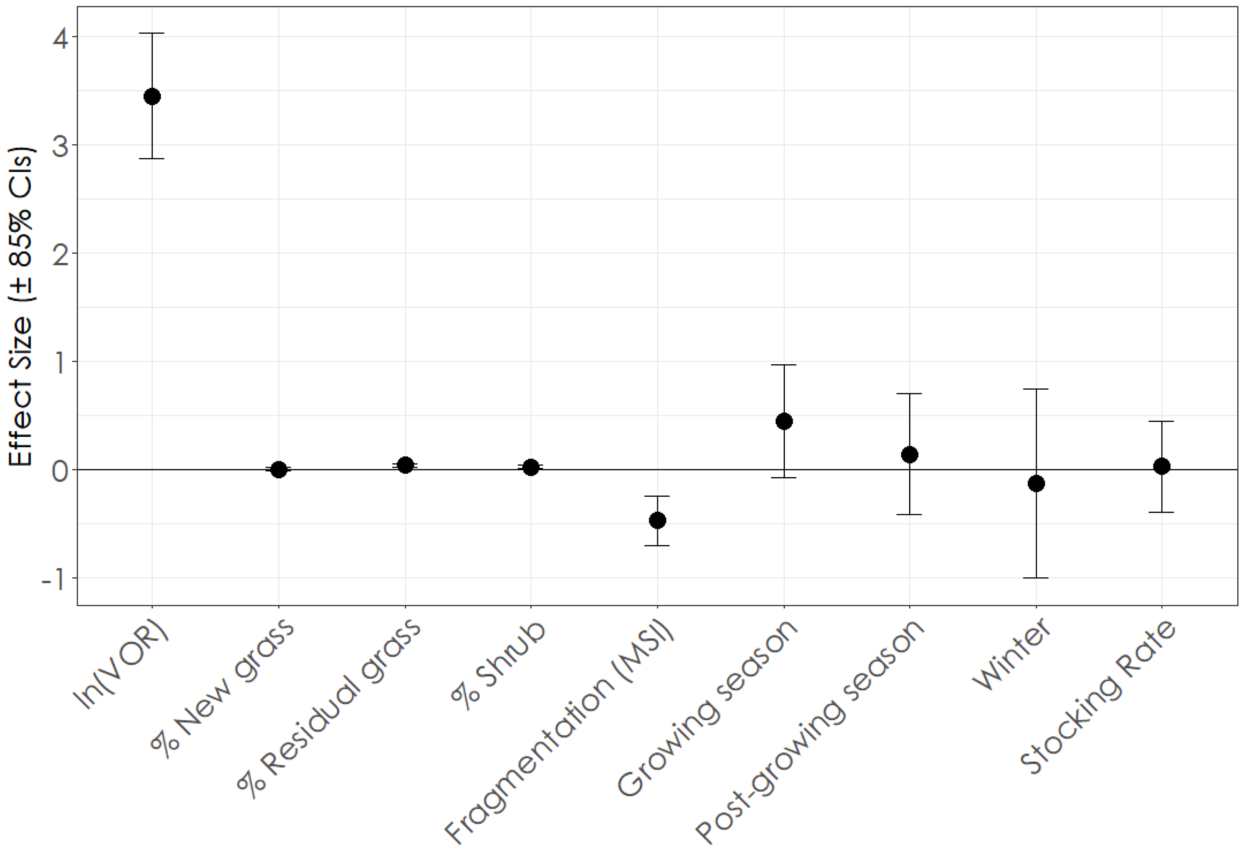

Figure 3. Model-averaged effect size (*β* ± 85% confidence intervals) for each variable in the analysis examining sharp-tailed grouse nest site selection in 2016-18. Parameters for each grazing season represent effect sizes in relation to the reference category of rested pastures.

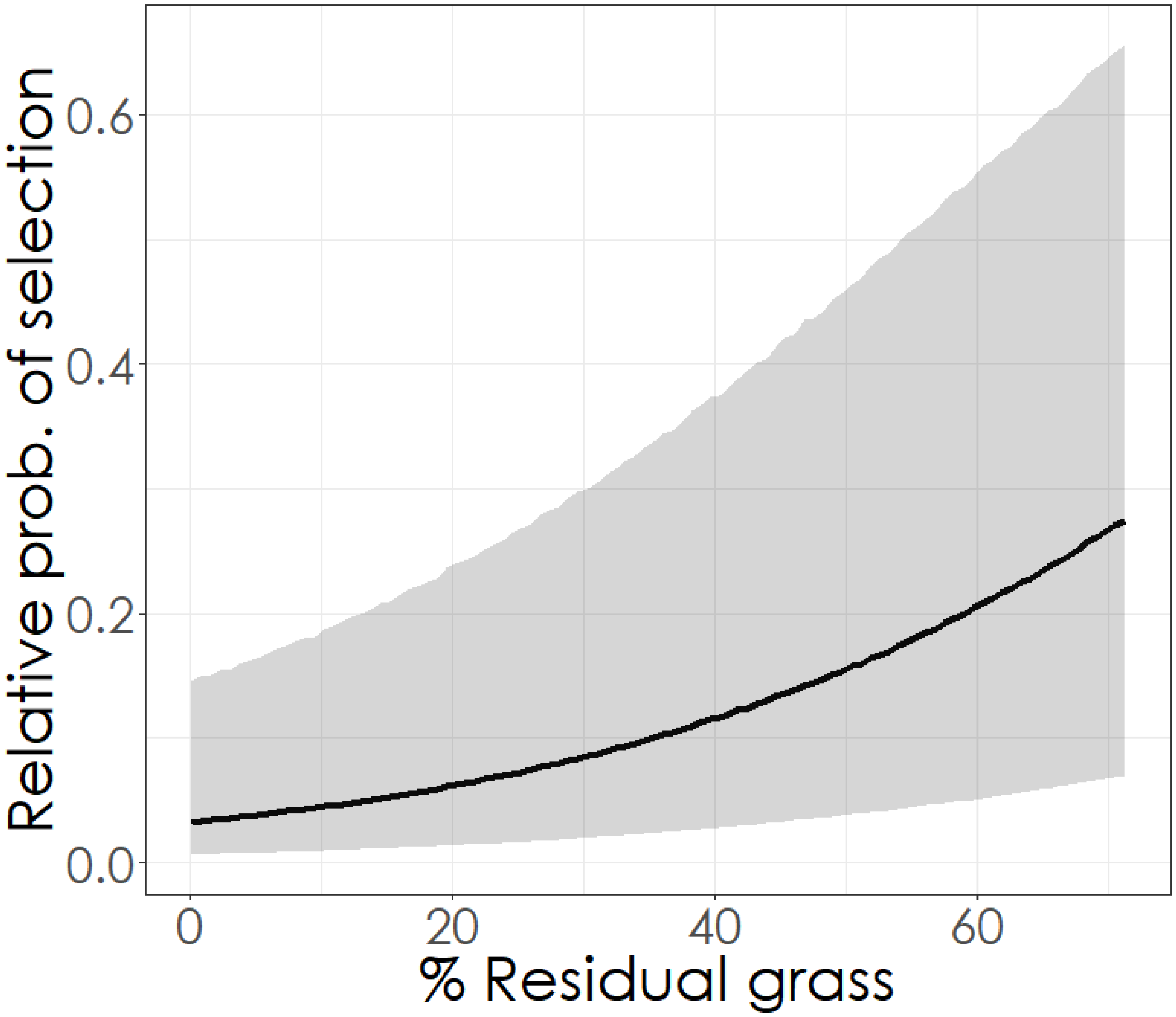

Figure 4. Estimated probability of nest site selection in relation to residual grass cover, with 85% confidence intervals shown in grey.

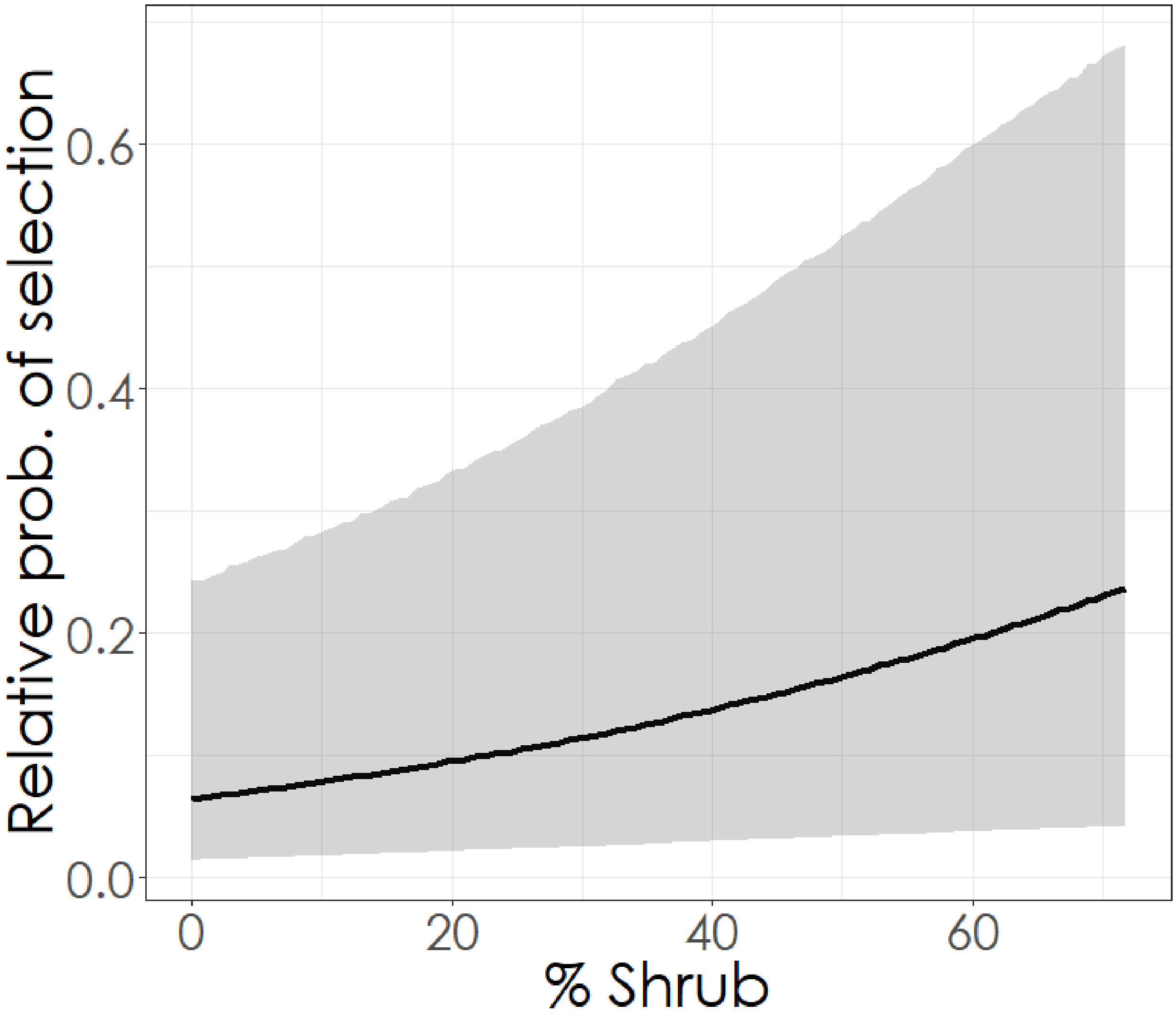

Figure 5. Estimated probability of nest site selection in relation to percent shrub cover, with 85% confidence intervals shown in grey.

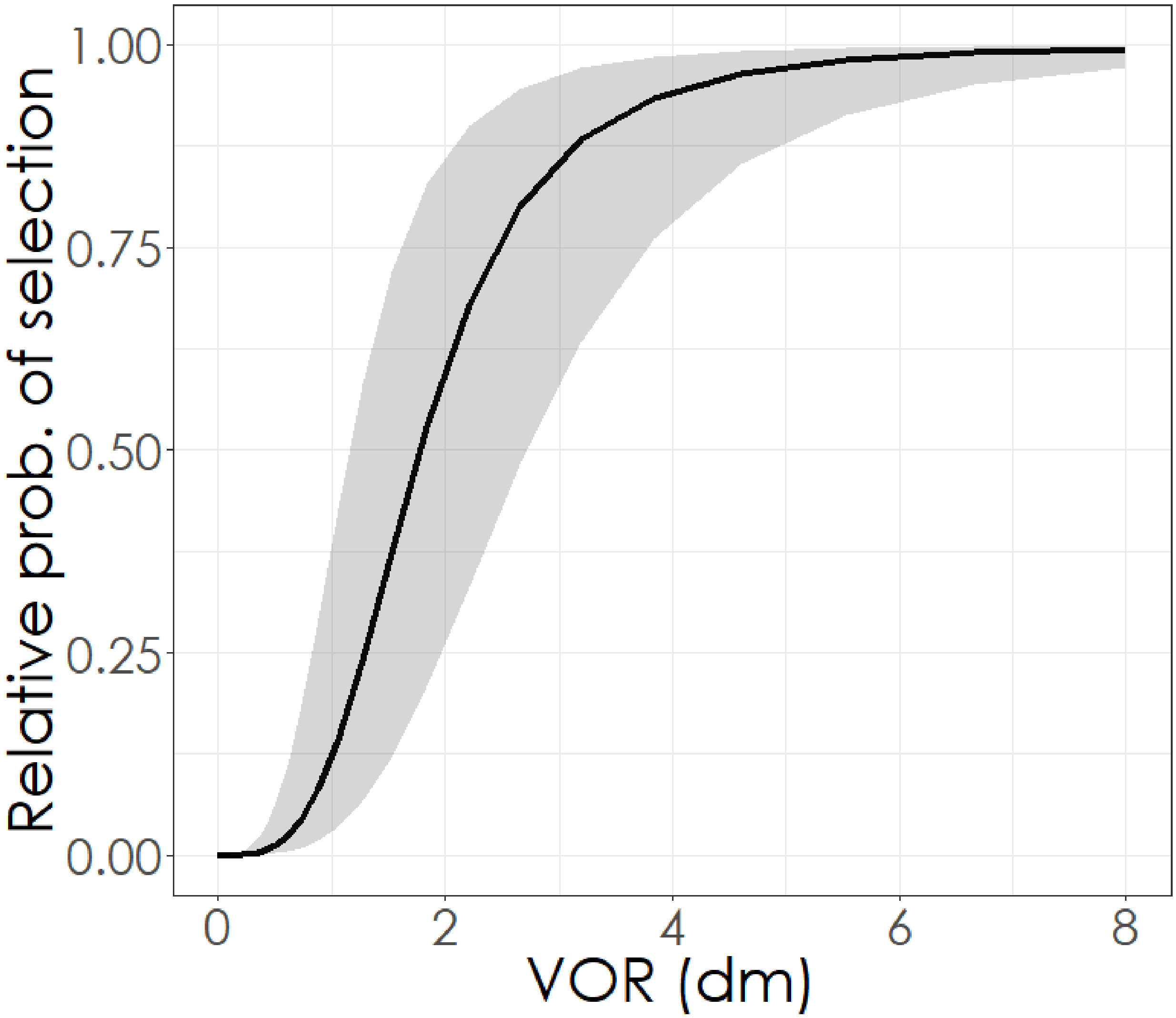

Figure 6. Estimated probability of nest site selection in relation to visual obstruction (VOR), with 85% confidence intervals shown in grey.

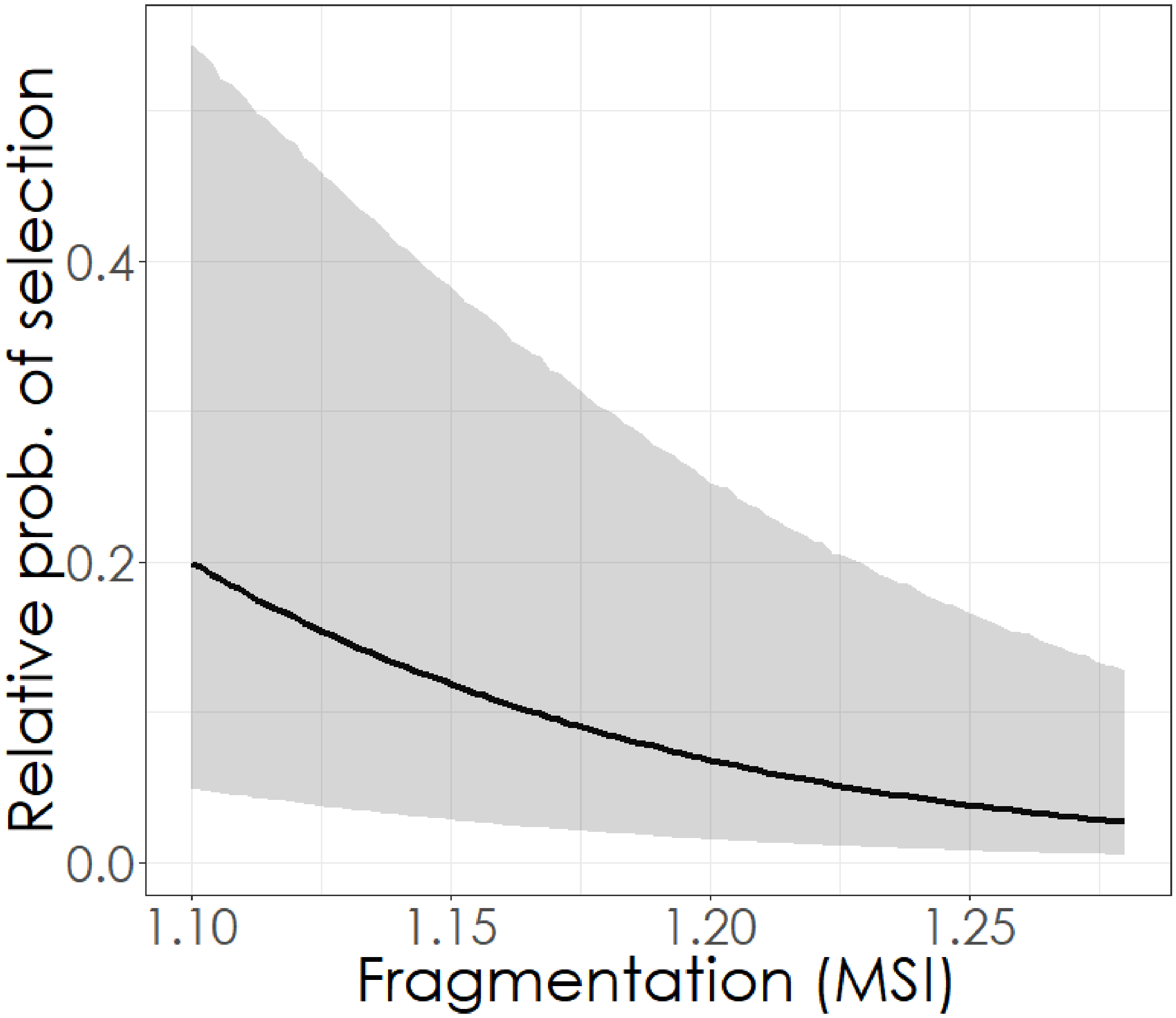

Figure 7. Estimated probability of nest site selection in relation to mean shape complexity (MSI), with 85% confidence intervals shown in grey.

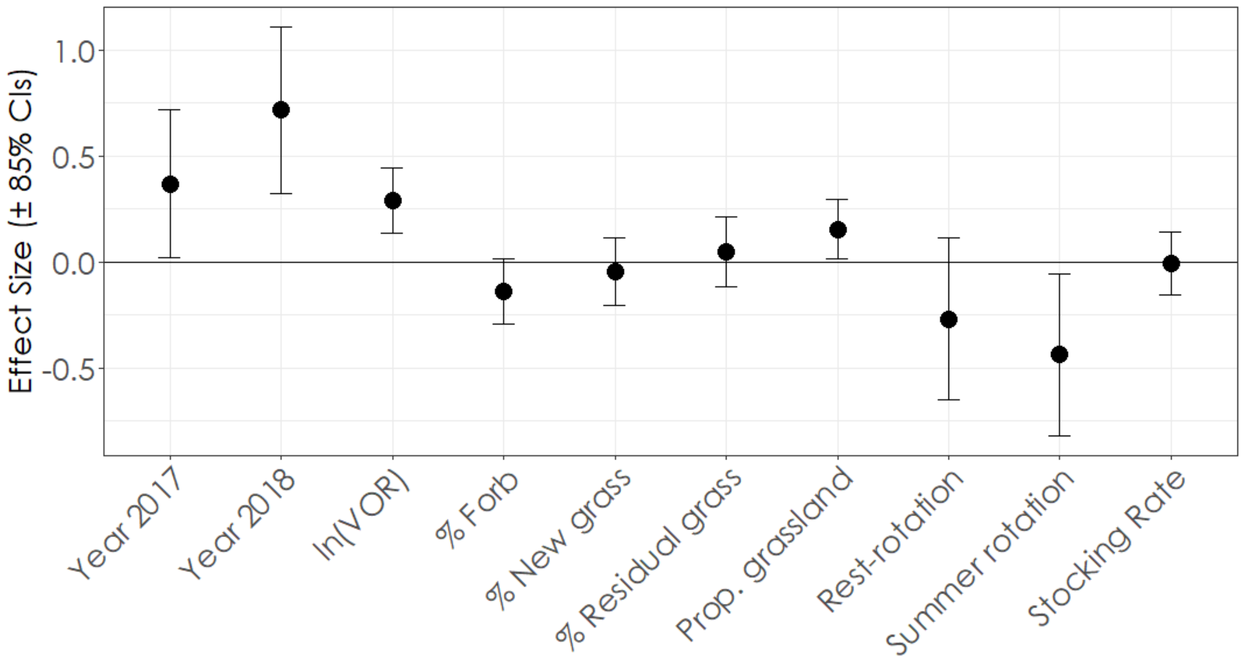

Figure 8. Model-averaged effect size (β ± 85% confidence intervals) for each variable in the analysis examining sharp-tailed grouse nest survival in 2016-18. Parameters for each grazing system represent effect sizes in relation to the reference category of season-long grazing and the year variables are measured in relation to 2016.

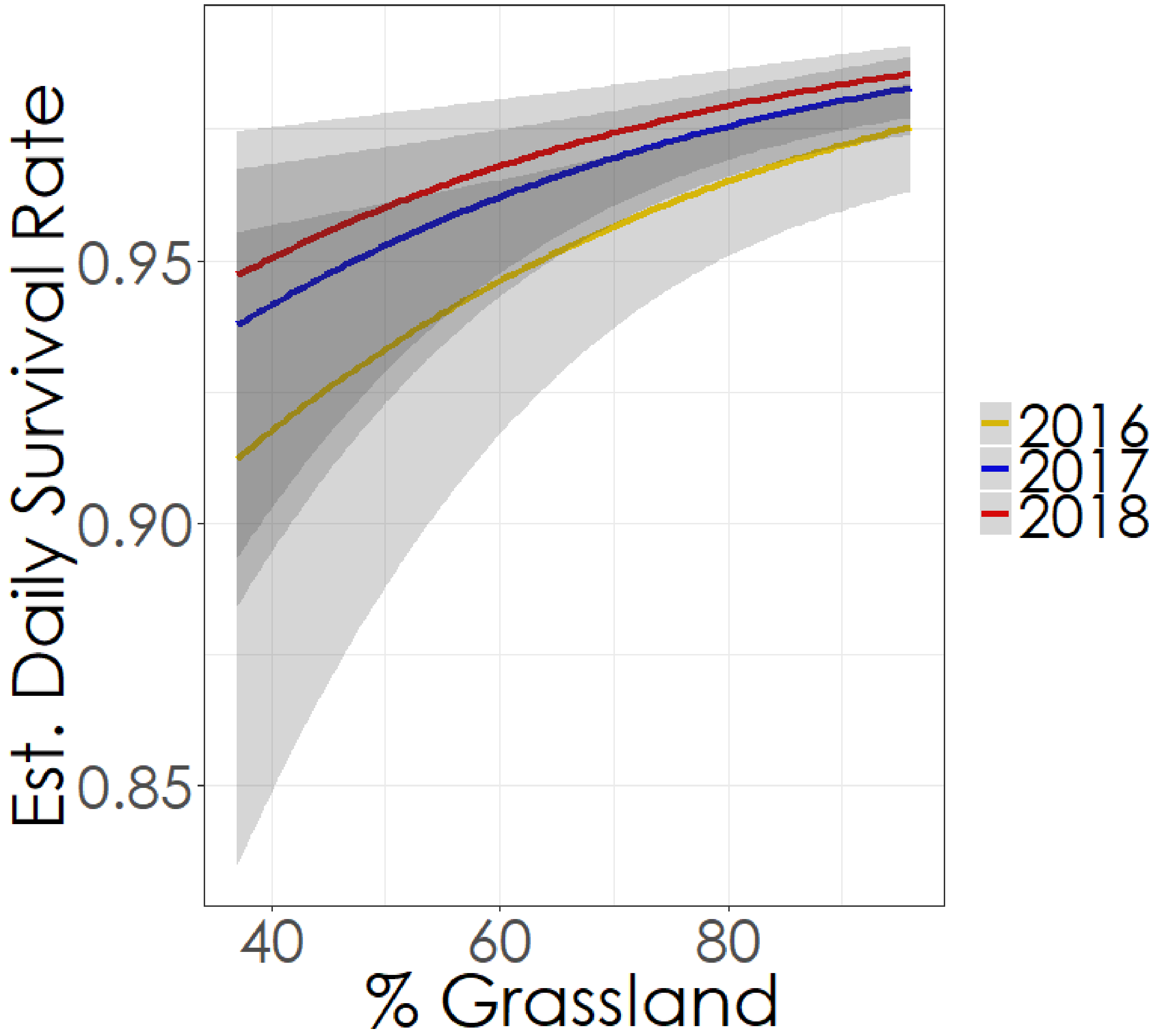

Figure 9. Estimated daily nest survival by year in relation to proportion grassland, with 85% confidence intervals shown in grey.

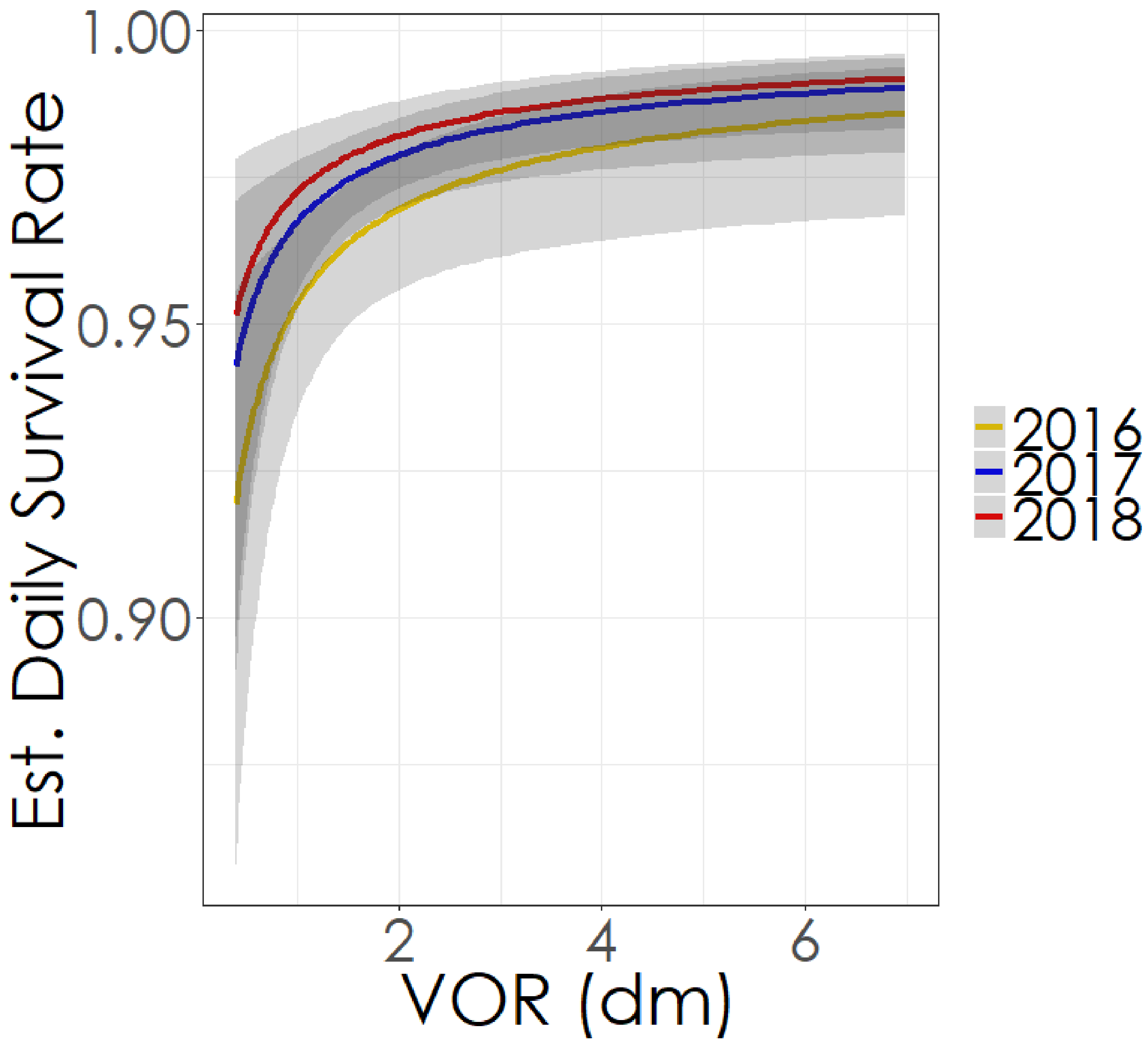

Figure 10. Estimated daily nest survival by year in relation to visual obstruction (VOR), with 85% confidence intervals shown in grey.

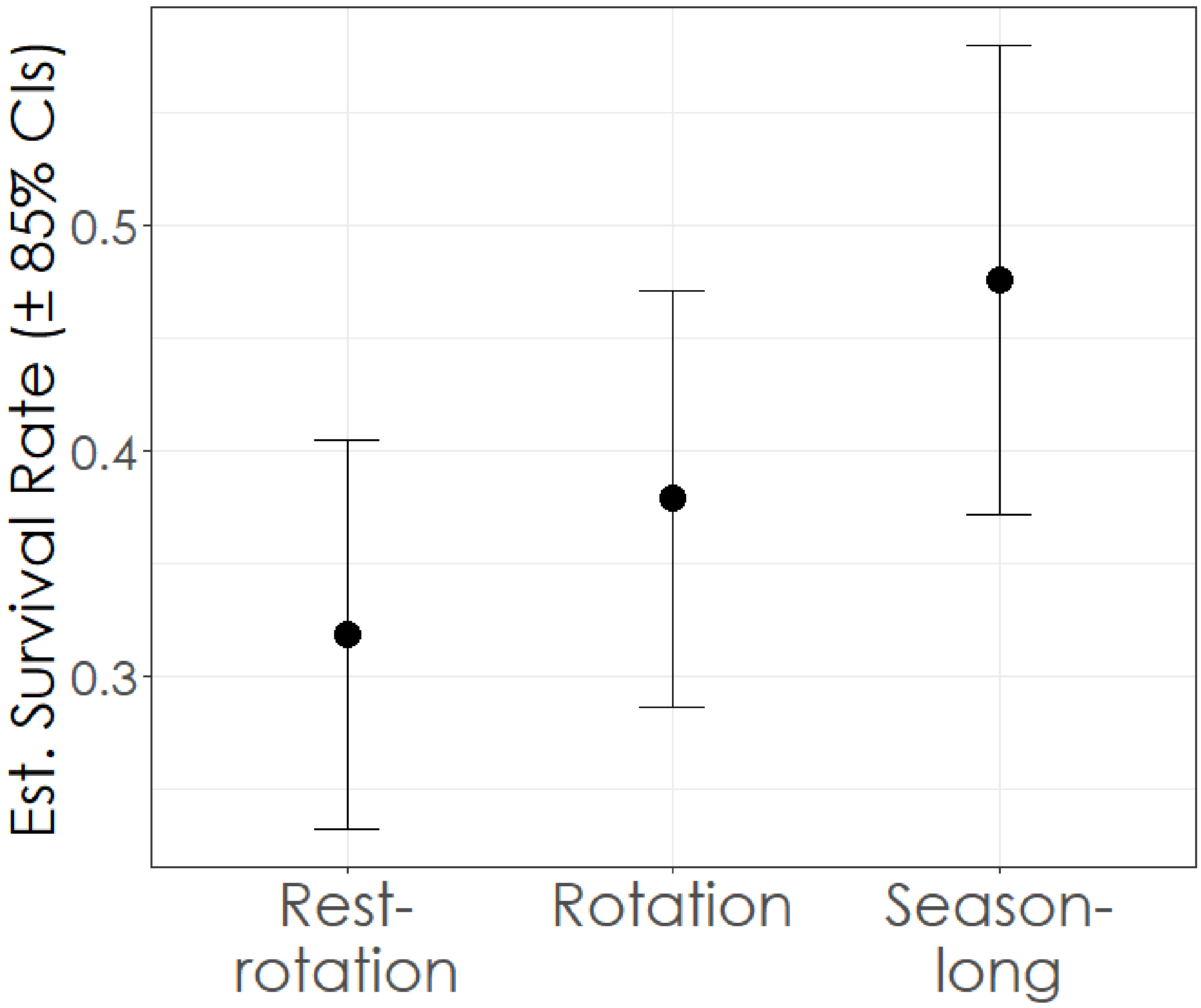

Figure 11. Estimated overall nest survival (± 85% confidence intervals) for sharp-tailed grouse in each of the three grazing treatments in 2016-18.

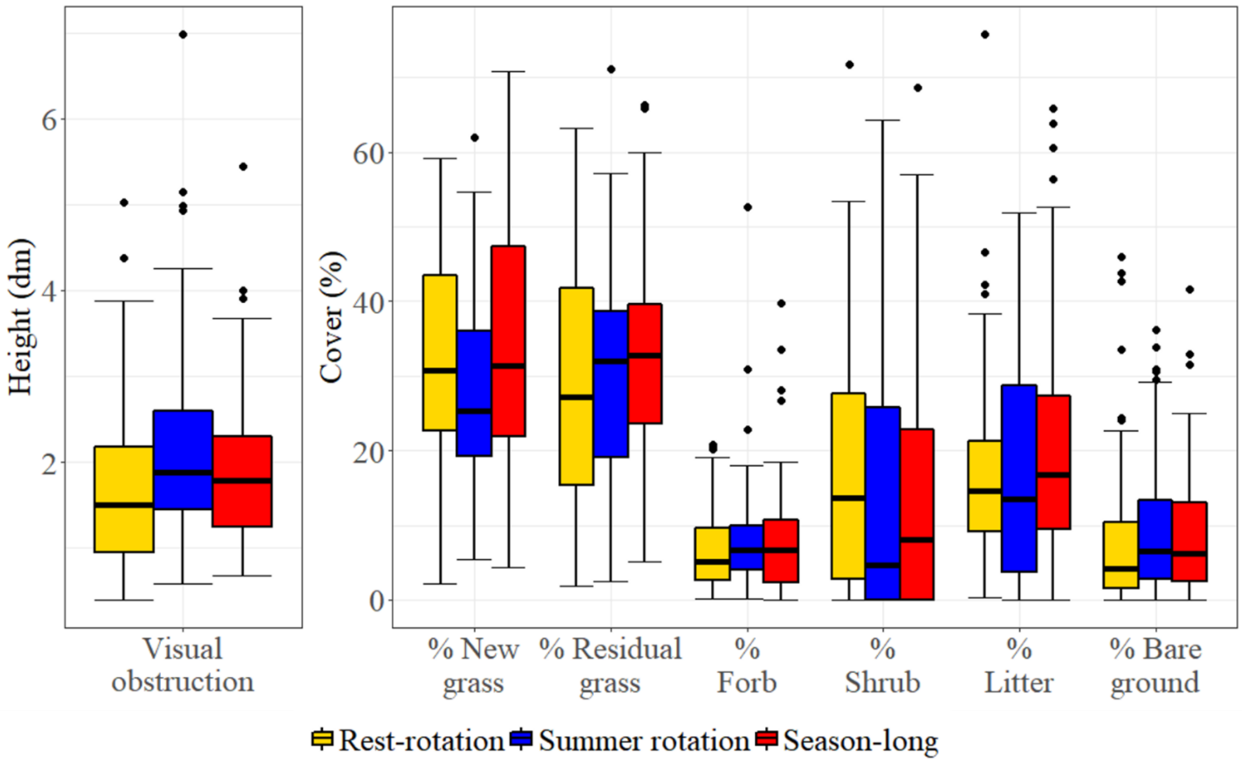

Figure 12. Vegetation measurements at nest sites in each grazing treatment.

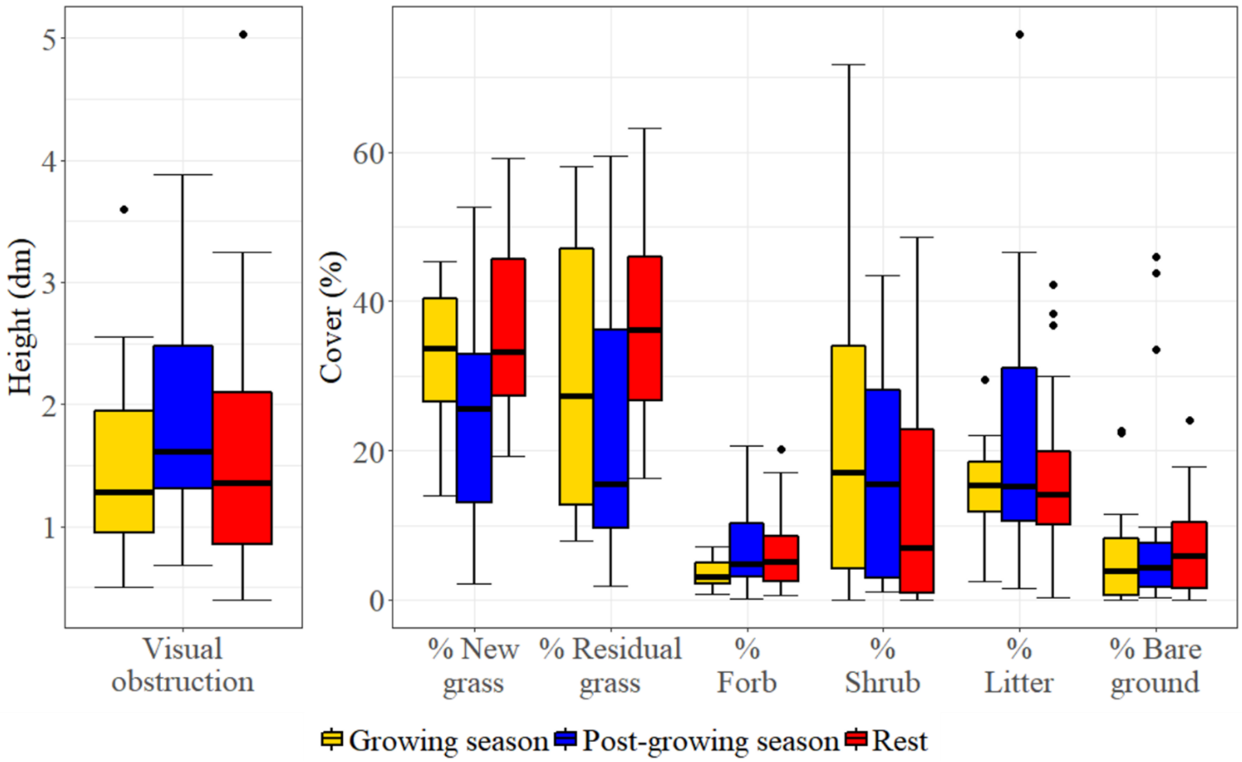

Figure 13. Vegetation measurements at nest sites within the rest-rotation system separated by treatment.

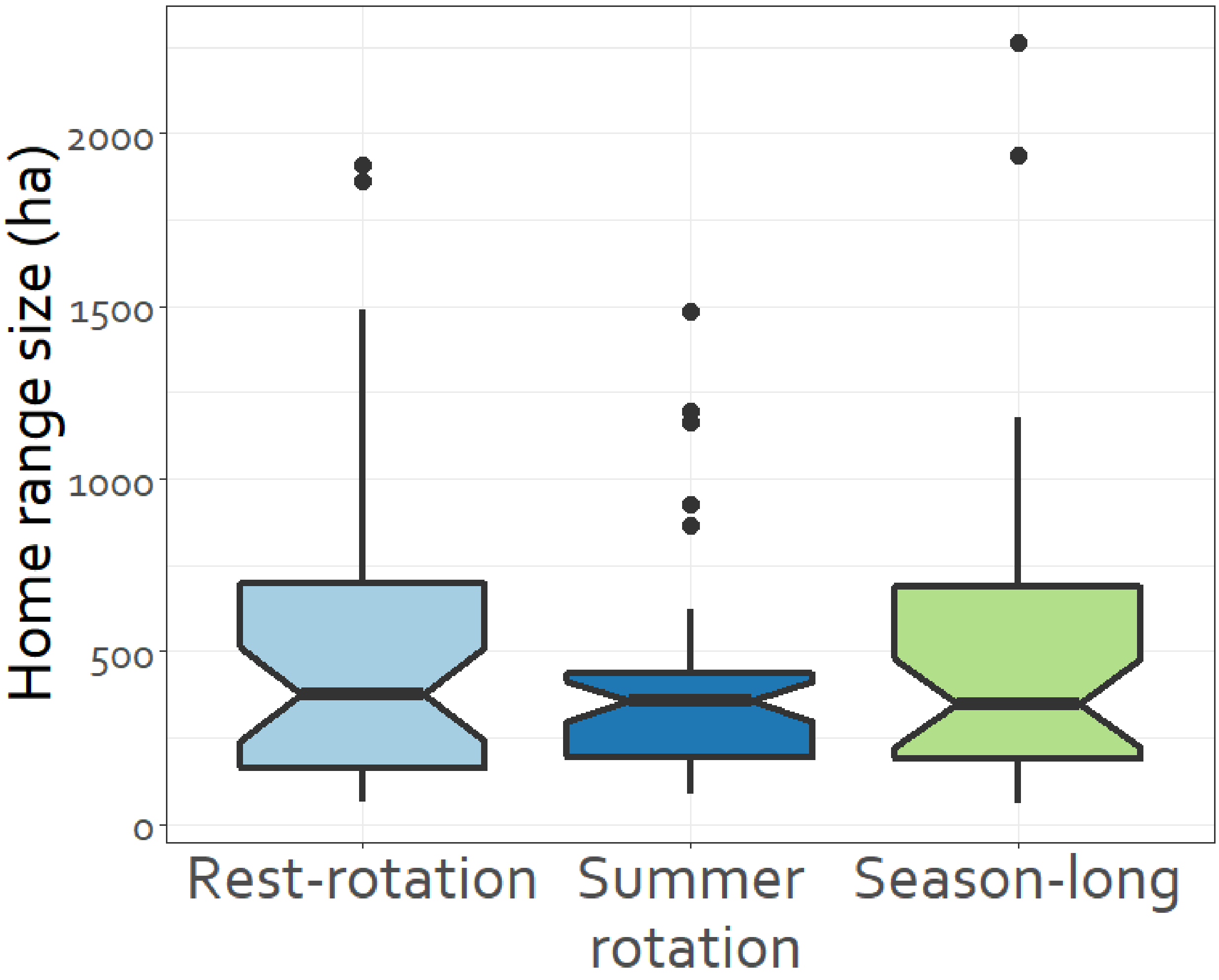

Figure 14. Female sharp-tailed grouse breeding season home range size (± SE) by grazing system. An individual female's home range was assigned to a grazing treatment according to the system at the home range centroid.