



Research Article

Occupancy Modeling of Ruffed Grouse in the Black Hills National Forest

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ABSTRACT Ruffed grouse (*Bonasa umbellus*) are a popular game bird and the management indicator species for quaking aspen (*Populus tremuloides*) in the Black Hills National Forest (BHNF), which requires development of a robust monitoring protocol to evaluate trends in ruffed grouse populations. We used roadside drumming surveys in spring 2007 and 2008 to estimate ruffed grouse occupancy and detection probabilities in the BHNF while simultaneously assessing the influence of sampling and site covariates on these processes. Ruffed grouse occupancy estimates were constant between spring 2007 and 2008 ($\Psi = 0.12$, $SE = 0.03$) and were positively influenced by the amount of aspen surrounding the site. Detection probability estimates were constant between spring 2007 and 2008 ($p = 0.27$, $SE = 0.06$) and were influenced by survey date in a quadratic form and negatively influenced by wind speed and time of the survey. Collectively, our results demonstrated that ruffed grouse occupancy and detection probabilities in the BHNF were low. Occupancy could be increased by increasing the extent of aspen. To improve monitoring efficiency and maximize probability of detecting ruffed grouse, ruffed grouse monitoring should be conducted during the peak of drumming (mid-May), during favorable weather conditions such as low wind speeds and little precipitation, and during early morning, near sunrise. © 2011 The Wildlife Society.

KEY WORDS Black Hills National Forest, *Bonasa umbellus*, detection probability, drumming surveys, occupancy modeling, ruffed grouse.

Ruffed grouse are a popular game species that inhabit early successional forest with inclusions of mature vegetation (e.g., aspen [*Populus* spp.]) for cover from predators and acquisition of food (Gullion 1967, Kubisiak 1985, Johnsgard 1989, Maxson 1989, Sharpe et al. 1997). Because ruffed grouse depend on multiple forest age-classes and dense woody cover, they are considered an important indicator species for the condition and abundance of aspen communities (Barber et al. 1989). As a result, ruffed grouse were named the management indicator species for aspen in the Black Hills National Forest (BHNF; U.S. Forest Service 1997).

Fire suppression, cattle grazing, and timber harvest practices have caused drastic changes in the composition of forest vegetation in the BHNF (Bartos and Shepperd 2003). Because of these changes, aspen communities have declined and many have been replaced by either white spruce (*Picea glauca*) or ponderosa pine (*Pinus ponderosa*), which is believed to have contributed to the reduction of ruffed grouse populations in the BHNF. As a result, managers used burning, cutting, and fencing the last 20 years to slow aspen declines (U.S. Forest Service 1997, Bartos and Shepperd 2003). Monitoring is necessary to evaluate the current status of ruffed grouse in the BHNF and determine whether aspen management and associated strategies are effective in increasing ruffed grouse populations in the BHNF. Consistent, statistically defensible monitoring will provide

managers with important ruffed grouse status, trend, and habitat association information crucial for management of ruffed grouse and aspen in the BHNF.

Historic monitoring of ruffed grouse in the BHNF has not effectively evaluated ruffed grouse population trends due to the inconsistency of surveys, inherent bias from conducting surveys only in vegetation types where ruffed grouse were expected to occur, and failure to consider imperfect detection (Science Applications International Corporation [SAIC] 2005). Occupancy modeling along with probabilistic sampling of the BHNF is one alternative for monitoring ruffed grouse in the BHNF that overcomes many of the current deficiencies. Occupancy models have become popular because they do not assume all individuals are detected, only require the investigator to determine presence or absence of the species from repeated surveys, and can be robust predictors of the proportion of the study area occupied when appropriate predictor variables are considered (MacKenzie et al. 2002, Crossland et al. 2005, MacKenzie et al. 2006). Our objective was to estimate occupancy and detection probabilities of ruffed grouse in the BHNF during spring 2007 and 2008 and assess the influence of vegetation, survey date and time, and weather conditions on these processes.

STUDY AREA

The BHNF was located in the western portion of South Dakota and included the Bear Lodge Mountains of north-eastern Wyoming. Elevation ranged from 1,066 m to 2,207 m. Annual rainfall in the BHNF exceeded 50.8 cm per year and varied with elevation (Ball et al. 1996). The BHNF included 500,000 ha of a variety of vegetation types,

Received: 22 December; Accepted: 4 May 2010

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consisting primarily of ponderosa pine (84%), quaking aspen (4%), and white spruce (2%). Other vegetation types comprised <10% of the BHNF, including paper birch (*Betula papyrifera*), bur oak (*Quercus macrocarpa*), hophornbeam (*Ostrya virginiana*), and green ash (*Fraxinus pennsylvanica*; Hoffman and Alexander 1987, Froiland 1990). Common shrubs included western snowberry (*Symphoricarpos occidentalis*), white coralberry (*S. albus*), kinnikinnick (*Arctostaphylos uva-ursi*), and common juniper (*Juniperus communis*; Severson and Thilenius 1976, Hoffman and Alexander 1987). Our study area encompassed the northern two-thirds of the BHNF, north of Highway 16. We used Highway 16 as our southern boundary because ruffed grouse were nearly absent south of Highway 16 (M. A. Rumble, U.S. Forest Service, unpublished data).

METHODS

Sample Site Determination

Prior to fieldwork, we used published information to estimate the number of sites and repeat surveys required for each site to obtain a desired precision. Occupancy and probability of detecting ruffed grouse were unknown in the BHNF so we used detection probability estimates from Minnesota (Zimmerman 2006) and abundance estimates from previous surveys in the BHNF (SAIC 2005) to guide our sample size calculations. We assumed occupancy probabilities would be heterogeneous throughout the BHNF; therefore, we stratified the BHNF into 3 vegetation strata representing high, medium, and low proportions of aspen (i.e., ha aspen/ha total vegetation) using the Resource Information System data from the BHNF.

Using a standard occupancy design (MacKenzie 2005, MacKenzie and Royle 2005), an assumed detection probability of 0.31 (Zimmerman 2006), and occupancy probabilities of 0.2, 0.3, and 0.4 (for low, medium, and high vegetation strata, respectively), we computed the number of sites and repeat surveys at each site to achieve our desired precision ($SE = 0.05$) for occupancy and detection probability estimates (MacKenzie and Royle 2005). Because of the uncertainty of parameters we used to estimate sample size, and because we anticipated that some sites could not be reached, we increased the number of prospective survey sites by 50% in each stratum.

We used ArcGIS 9.2 and a stratified random sampling design without replacement to identify survey sites along secondary and primitive roads in the BHNF. We did not include sites along primary roads (paved or upgraded gravel roads) because traffic could interfere with our ability to hear drumming ruffed grouse. We defined a site as the farthest distance that ruffed grouse could be heard drumming from a survey point, which we confirmed to be 550 m in the BHNF. Thus, we constrained sampling sites to be >1.6 km apart to ensure independence and no overlap between sites.

The BHNF had one of the highest road densities (3.2 km/km²) of any national forest, consisting primarily of secondary (i.e., gravel) and primitive (i.e., dirt) roads (Rumble et al. 2005). Thus, we assumed that ruffed grouse drumming

surveys along secondary and primitive roads would be representative of the entire study area. To confirm this assumption, we placed a 550-m buffer around all secondary and primitive roads in ArcGIS. This buffer covered approximately 91.3% of the study area, which confirmed that conducting drumming surveys from roads adequately represented the BHNF.

Field Methods

We conducted roadside drumming counts (Petraborg et al. 1953) in the BHNF from 2 April 2007 through 31 May 2007, 4 September through 27 October 2007, and 14 April 2008 through 7 June 2008. We began surveys half an hour before sunrise and navigated to survey sites using Global Positioning Systems. At each site we listened for 5 min and recorded whether we detected drumming grouse (McBurney 1989). We then recorded time, date, temperature, wind speed (using a hand-held anemometer), weather conditions, azimuth, and estimated distance (<50 m, between 50 m and 150 m, >150 m) to drumming ruffed grouse. We limited the timing of surveys to <5 hr after sunrise ($\bar{x}$ = approx. 2.0 hr after sunrise) because occurrence and frequency of drumming decreases throughout the day (Archibald 1976, Maxson 1989).

On successive surveys, we varied the times that we visited sites to reduce bias that might be associated with the time we conducted surveys. We also ensured weather conditions were favorable by following a specific protocol that prohibited surveys when wind speed exceeded 16 km/hr or during heavy snow or rain. Finally, we rotated observers between repeat surveys to reduce observer bias.

Ruffed grouse will drum in autumn, presumably to claim breeding territories for the following spring (McBurney 1989). Although literature suggests that ruffed grouse are not as active at their drumming sites in autumn (Bump et al. 1947), the weather, road conditions, and lower noise levels (e.g., breeding bird vocalizations) during autumn make surveys logistically more feasible. Therefore, we evaluated whether autumn drumming surveys were more efficient than spring surveys. During autumn surveys, we surveyed the same sites and collected the same data as in the spring; however, we only surveyed sites in regions where occupancy probabilities were high and sites where we detected ruffed grouse the previous spring. We sampled only sites with high probabilities of occupancy because we hypothesized that drumming behavior would not be as frequent or consistent in autumn and we wanted to assess whether it would be feasible to locate ruffed grouse during autumn (Bump et al. 1947). We only sampled during one autumn season due to the poor results of surveys during autumn 2007.

A Priori Models

To examine the influence of sampling and site covariates on occupancy and detection probabilities, we developed a priori models based on published literature and evaluated them using an information-theoretic approach (Burnham and Anderson 2002). We chose 15 models to evaluate effects of weather (i.e., wind, temp, precipitation), observer (full-time technician or volunteer), temporal factors (yr, day of

Table 1. Description of covariates we used in a priori models that assess factors that influenced probability of occupancy and detection of ruffed grouse in the Black Hills National Forest during spring 2007 and 2008 drumming surveys.

Variable	Description
Vegetation	
Aspen	Quaking aspen (ha) ^a
Pine	Ponderosa pine (ha) ^a
Spruce	White spruce (ha) ^a
Strata	Categorical variable representing high, medium, and low proportions of aspen
Stand age	
3B	Area (ha) with 40–70% sapling cover ^a
3C	Area (ha) with >70% sapling cover ^a
4B	Area (ha) with 40–70% mature tree cover ^a
4C	Area (ha) with >70% mature tree cover ^a
Weather	
Wind	Average wind speed (km/hr) during the 5-min survey
Temp	Average temp (°C) during the survey
Precip	Categorical variable describing if precipitation occurred during the survey
Observer	
Tech	Categorical variable describing whether the observer performing the survey was a full-time technician
Temporal	
y	Yr of survey
Time	Time of survey
Date	Day of the yr of the survey
Date^2	Day of the yr of the survey in a quadratic form

^a Calculated within a 550-m buffer around each site.

the yr, time of day), and vegetation strata (high, medium, and low proportions of aspen; Table 1) on detection probabilities. We then developed 15 additional models to evaluate the influence of site covariates (stand age category, aspen, spruce, and pine area within 550 m of the survey point; Table 1) on occupancy probability. In each occupancy model, we incorporated the covariates included in the most supported detection probability models (see the Analytical Methods section). A detailed description of each model, hypothesized covariate effects, and a rationale for each model is available in Hansen (2009).

Analytical Methods

We estimated occupancy (Ψ) and detection (p) probabilities for ruffed grouse in the BHNF using data from spring 2007 and 2008 drumming surveys. We used Program PRESENCE (MacKenzie et al. 2006) to estimate occupancy and detection probabilities and compute estimates for covariates included in the most-supported models (MacKenzie et al. 2006). We used the multi-season parameterization in Program PRESENCE that calculates seasonal occupancy estimates (MacKenzie et al. 2006). Using this parameterization, we determined whether occupancy and detection probability changed between years.

We used a 2-stage approach in our model selection procedures (e.g., Franklin et al. 2000, Washburn et al. 2004). In the first stage, we compared a priori models that evaluated the influence of sampling and site covariates on detection probability while holding occupancy constant (i.e., $\Psi[\cdot]P[\text{covariate}]$). In the second stage, we modeled the influence of site covariates on occupancy while incorporating the

covariates included in detection probability models (from stage 1) that contained 90% of Akaike weight (i.e., $\Psi[\text{covariate}]p[\text{covariates from the most supported detection models}]$; Bailey et al. 2004, Olson et al. 2005, MacKenzie et al. 2006, Kroll et al. 2007). By incorporating a 2-stage design, we reduced our candidate model set while still evaluating a sufficient set of covariates that might have caused heterogeneity in occupancy and detection probabilities.

We ranked models based on Akaike's Information Criterion, with an adjustment for small sample size (AIC_c), and Akaike weights (w_i ; Burnham and Anderson 2002). We addressed model selection uncertainty by calculating model-averaged covariate estimates for occupancy models in the 90% Akaike weight confidence set (Burnham and Anderson 2002). After model averaging, we calculated odds ratios and 95% odds ratio confidence intervals for covariate estimates to assess which covariates in the 90% confidence set influenced occupancy and detection probabilities. We assumed covariates with odds ratio confidence intervals that did not include 1 influenced occupancy and detection probabilities, whereas odds ratio confidence intervals that included 1 did not influence these probabilities. To examine effects of occupancy and detection probability covariates in the model-averaged occupancy model, we plotted the fitted relationship of each occupancy and detection covariate while keeping the other covariates constant at their mean values.

We determined model goodness-of-fit by applying the Pearson chi-square statistic and completing 10,000 parametric bootstraps to our global occupancy models each sampling year (MacKenzie and Bailey 2004). We used parametric bootstraps to determine $\hat{c}$ (MacKenzie and Bailey 2004), where we assumed models with $\hat{c}$ values near 1 were adequate descriptors of the data (Burnham and Anderson 2002). We used a k -fold cross-validation design (Boyce et al. 2002) to evaluate the predictive ability of our model-averaged occupancy model because of its similarity to a resource selection function (Manly et al. 1993). We evaluated correlations between the frequency of observed and expected observations in each occupancy probability bin using Spearman-rank correlations (Boyce and McDonald 1999, Boyce et al. 2002, Johnson et al. 2006). We expected a good predictive model to demonstrate a large, positive correlation between observed and expected frequencies (Johnson et al. 2006). We did not evaluate a different occupancy model for each season because we hypothesized that covariates influencing occupancy of ruffed grouse between successive years would not change.

RESULTS

We surveyed 137, 149, and 116 sites in the high, medium, and low vegetation strata, respectively, in spring 2007 and 2008. We surveyed each site ≥ 3 times, except for 16 sites that we sampled only twice in spring 2007 and 2 sites we sampled only twice in spring 2008. We surveyed 137, 149, and 29 sites ≥ 4 times each in the high, medium, and low vegetation strata, respectively, in autumn 2007. During spring 2007,

Table 2. Ranking of candidate models that assess the influence of temporal and spatial variables on detection probability (P) of ruffed grouse in the Black Hills National Forest during spring 2007 and 2008 drumming surveys, assuming occupancy probability (Ψ) is constant. K is the number of covariates in the model, AIC_c is Akaike's Information Criterion adjusted for small sample size, ΔAIC_c is the difference in AIC_c value from the top model, and w_i is the Akaike weight. Only models with Akaike weights >0 are shown.

Model ^a	K	AIC_c	ΔAIC_c	w_i
$\Psi(\cdot), p(\text{Date}^2 + \text{wind} + \text{time})$	7	624.24	0.00	0.68
$\Psi(\cdot), p(\text{Date}^2 + \text{wind} + \text{time} + \text{precip})$	8	626.24	2.00	0.25
$\Psi(\cdot), p(\text{Date}^2 + \text{wind})$	6	629.41	5.17	0.05
$\Psi(\cdot), p(\text{Date}^2 + \text{wind} + \text{precip})$	7	631.60	7.37	0.01
$\Psi(\cdot), p(\text{global})$	13	635.31	11.07	<0.01

^a See Table 1 for definition of covariate symbols.

autumn 2007, and spring 2008, we detected ruffed grouse at 30 sites, 2 sites, and 33 sites, respectively.

The most supported model for detection probability included the day of the year, wind speed, and time covariates (Table 2). Model selection procedures suggested that detection did not change from 2007 to 2008; thus, we estimated detection probability as $p = 0.27$ (SE = 0.06) for both years. The day of the year was related to detection probability in a quadratic form, whereas wind speed and time were negatively related to detection probability. Predicted values of detection probability were essentially zero at the beginning of April, gradually increased to a peak on 19 May, and decreased into early June (Fig. 1). Additionally, estimated detection probability was highest at low wind speeds and declined towards zero at wind speeds ≥ 16 km/hr (Fig. 2). Finally, estimated detection probability was highest when we conducted the survey early in the morning, near sunrise, and decreased gradually as the day progressed (Fig. 3).

The global model for occupancy and detection passed goodness-of-fit measures for spring 2007 ($\chi^2 = 6.52$, P -value = 0.77, $\hat{c} = 0.62$) and 2008 ($\chi^2 = 11.27$, P -value = 0.17, $\hat{c} = 0.97$). The season-constant occupancy model

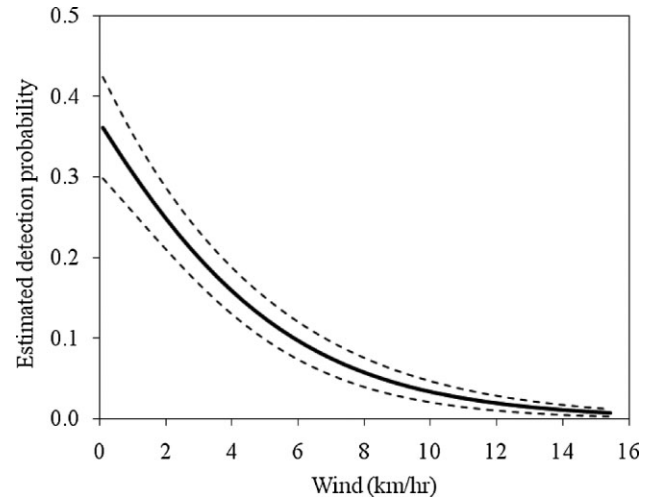


Figure 2. Influence of average wind speed (km/hr) on probability of detecting ruffed grouse in the Black Hills National Forest during spring 2007 and 2008 drumming surveys. Dashed lines represent the upper and lower 95% confidence limits.

performed better than the season-dependent model; therefore, estimated occupancy probability was $\Psi = 0.12$ (SE = 0.03) for both years. Two occupancy models fell within the 90% Akaike weight confidence set (Table 3). These models suggested that the area of aspen and spruce vegetation surrounding a site were the only variables that influenced occupancy.

Model-averaged covariate estimates and odds ratios (Table 4) suggested that the area of aspen vegetation within 550 m of a site had the greatest influence on ruffed grouse occupancy. Probability of occupancy increased by an average of 5.7% for each 5-ha increase in the area of aspen (Fig. 4a). The area of spruce vegetation within 550 m of a site also had a minor positive influence on occupancy; however, the 95% odds ratio confidence intervals for this covariate included 1. Probability of occupancy increased by an average of 2.9% for

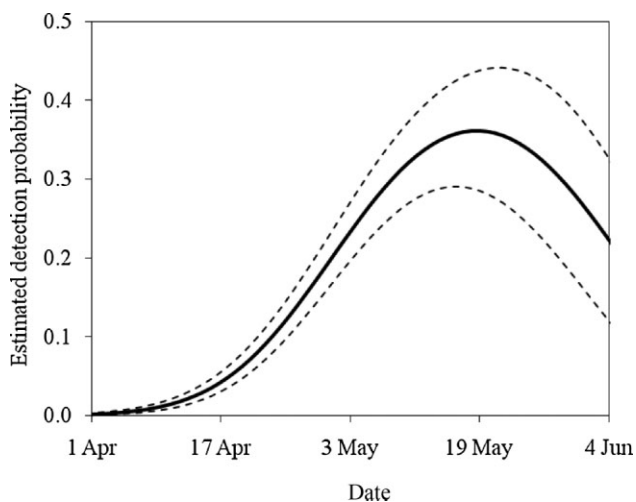


Figure 1. Influence of date on probability of detecting ruffed grouse in the Black Hills National Forest during spring 2007 and 2008 drumming surveys. Dashed lines represent the upper and lower 95% confidence limits.

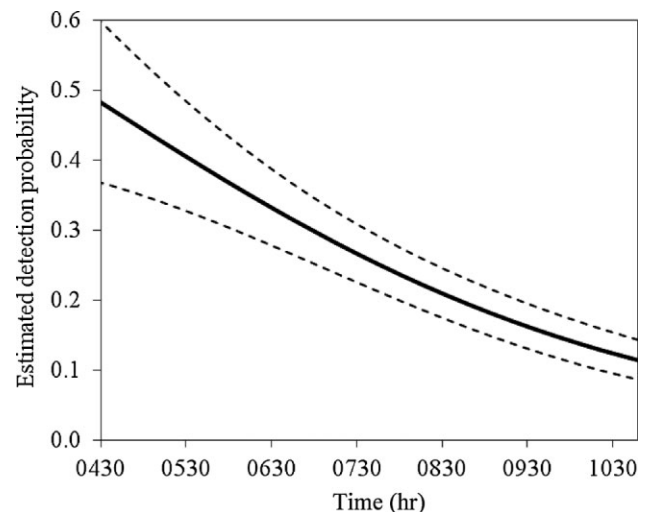


Figure 3. Influence of the time of day of the survey on probability of detecting ruffed grouse in the Black Hills National Forest during spring 2007 and 2008 drumming surveys. Dashed lines represent the upper and lower 95% confidence limits.

Table 3. Ranking of candidate models that assess the influence of temporal and spatial variables on occupancy probability (Ψ) of ruffed grouse during spring 2007 and 2008 surveys in the Black Hills National Forest. Covariates from the most supported detection models are incorporated in each model. K is the number of covariates in the model, AIC_c is Akaike's Information Criterion adjusted for small sample size, ΔAIC_c is the difference in AIC_c value from the top model, and w_i is the Akaike weight. Only models with Akaike weights >0 are shown.

Model ^a	K	AIC_c	ΔAIC_c	w_i
$\Psi(\text{aspen} + \text{spruce}), p(\text{best})^b$	10	603.77	0.00	0.82
$\Psi(\text{aspen}), p(\text{best})$	9	607.47	3.70	0.13
$\Psi(\text{aspen} + \text{pine}), p(\text{best})$	10	609.57	5.80	0.04
$\Psi(\text{strata}), p(\text{best})$	10	616.67	12.90	<0.01

^a See Table 1 for definition of covariate symbols.

^b Covariates from the most supported detection probability (p) models (Date², wind, time, and precip).

Table 4. Model-averaged covariate estimates, standard errors (SE), odds ratios, and 95% odds ratio confidence intervals (CI) for occupancy and detection probabilities of ruffed grouse in the Black Hills National Forest during spring 2007 and 2008.

Covariate ^a	Estimate	SE	Odds ratio	95% CI
Occupancy covariates				
Intercept	-1.94	0.22		
Aspen	0.66	0.16	1.93	1.40–2.65
Spruce	0.25	0.14	1.29	0.97–1.71
Detection covariates				
Intercept	-0.98	0.26		
Date	1.07	0.28	2.92	1.67–5.09
Date ²	-0.69	0.21	0.50	0.33–0.76
Wind	-0.67	0.19	0.51	0.34–0.76
Time	-0.39	0.14	0.68	0.52–0.88
Precip	-0.34	0.40	0.71	0.32–1.58

^a See Table 1 for definition of covariate symbols.

each 5-ha increase in the area of spruce (Fig. 4b). Our model-averaged occupancy model had a significant positive correlation between expected and observed occupancy frequencies across all k -fold cross-validation trials (Table 5), suggesting our model predicted occupancy probabilities well.

DISCUSSION

Occupancy probability of ruffed grouse in the BHNF was low and influenced by the area of aspen-dominated vegetation. Our study was the first to use occupancy modeling to estimate the status and trends of ruffed grouse in the BHNF. As a result, we cannot compare our occupancy results with previous abundance estimates in the BHNF or other parts of their range (SAIC 2005). Rather, we suggest our estimate of occupancy be used as a reference for future monitoring in the BHNF. Occupancy did not change from 2007 to 2008, suggesting a stable population; however, more years of occupancy estimates are necessary to determine trends of ruffed grouse in the BHNF. As we hypothesized, probability of ruffed grouse occupancy increased as the amount of quaking aspen surrounding a survey point increased. Ruffed grouse have been closely associated with vegetation stands dominated by aspen wherever their ranges intersect, such as in Minnesota (Gullion 1967, Gullion and

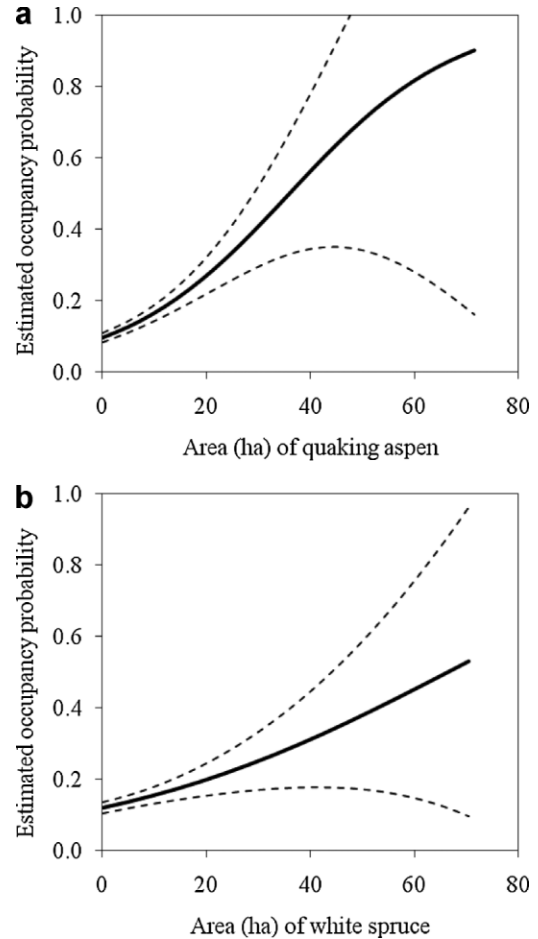


Figure 4. Influence of the area (ha) of quaking aspen (a) and white spruce (b) within 550 m of a site on probability of ruffed grouse occupancy in the Black Hills National Forest during spring 2007 and 2008. Area of aspen and spruce within a site ranged from 0 ha to approximately 70 ha; however, 96% and 98% of the sites had <30 ha of aspen and spruce, respectively. Thus, upper and lower 95% confidence limits (dashed lines) above 30 ha are large.

Svoboda 1972, Zimmerman and Gutiérrez 2008), Alberta (Boag and Sumanik 1969), Utah (Hewitt and Messmer 2000), and Idaho (Stauffer and Peterson 1985). However, ours is the first rigorous quantitative assessment of how ruffed grouse occupancy is related to aspen in the BHNF. Confirmation of this association validates the use of ruffed grouse as the indicator species for quaking aspen in the BHNF and further demonstrates the importance of aspen management to ruffed grouse.

Table 5. Spearman-rank correlation (r_s) of the model-averaged ruffed grouse occupancy model for each fold from k -fold cross-validation. We obtained data from ruffed grouse drumming surveys throughout the Black Hills National Forest in spring 2007 and 2008.

Fold	r_s	P -value
1	0.852	≤ 0.01
2	0.788	≤ 0.01
3	0.894	≤ 0.001
4	0.900	≤ 0.001
5	0.927	≤ 0.001
Combined	0.980	≤ 0.001

White spruce was also included in the most supported model in our occupancy analysis, suggesting that spruce might play a modest role in the distribution of ruffed grouse in the BHNF. White spruce is a shade-tolerant species that eventually invades quaking aspen stands (a shade-intolerant species; Ball et al. 1996). Thus, the inclusion of spruce in our occupancy model could be attributed to ruffed grouse occupying remnant pockets of aspen within a stand dominated by spruce. Stauffer and Peterson (1985) and Zimmerman (2006) found that ruffed grouse occasionally used mixed aspen and conifer stands more than pure aspen stands. Due to limitations of the Geographic Information System (GIS) data we used, we were not able to evaluate subdominant species or mixed stands in our analysis.

Estimates of detection probability for ruffed grouse drumming surveys in the BHNF were low but could be increased by conducting surveys during optimal times and conditions. Detection probability estimates for ruffed grouse in the BHNF were 6% lower than those estimated in Minnesota (Zimmerman and Gutiérrez 2007). Our lower estimates were likely due to the difference in timing of the peak of detection between the 2 areas. Most literature suggests that the peak of drumming occurs in mid- to late April (e.g., Gullion 1966, Rodgers 1981, Jones et al. 2005, Zimmerman and Gutiérrez 2007). In the BHNF, the peak of detection probability did not occur until the middle of May, suggesting the peak of drumming activity was later than what has been observed in other studies. Gullion (1966) and Zimmerman and Gutiérrez (2007) suggested that photoperiod influenced the peak of drumming in Minnesota, whereas Jones et al. (2005) observed that the peak of drumming coincided with initiation of nests by females in North Carolina. Alternatively, weather conditions and phenology of vegetation could also influence the timing of the drumming peak (Dorney et al. 1958, Gullion 1966). Although we do not know why the peak of detection was late in the BHNF, we do not believe weather conditions or plant phenology was the reason, because the peak of detection did not change significantly from 2007 to 2008. Instead, we speculate that the photoperiod or timing of nest initiation governs the peak timing of drumming and detection probability in the BHNF. Future monitoring in the BHNF should be completed during May to increase the probability of detecting ruffed grouse if they are present.

Probability of detecting ruffed grouse was also influenced by wind speed and time of day. As winds increased, probability of detecting ruffed grouse in the BHNF decreased rapidly. Strong winds do not discourage drumming activity; however, they do influence the ability of the observer to detect ruffed grouse drumming (Gullion 1966). Therefore, surveys should not be completed if wind speeds exceed 16 km/hr. Time of day also had a negative influence on detection probability. Archibald (1976) observed that ruffed grouse in Minnesota drummed throughout the day, depending on the time of the year, but drummed most consistently near sunrise. Ruffed grouse in the BHNF showed similar trends. Although it was possible to detect ruffed grouse later in the morning in the BHNF, probability of detecting a

drumming ruffed grouse was highest near sunrise. Future monitoring should complete surveys as close to sunrise as possible.

MANAGEMENT IMPLICATIONS

In the BHNF, ruffed grouse occupancy was low, but might be increased by increasing the area and extent of aspen-dominated communities. Based on correlations we documented, with each 5-ha increase in aspen-dominated vegetation communities within a 95-ha site, managers can expect probability of ruffed grouse occupancy to increase by approximately 5.7% for that site. Our occupancy estimate can serve as a baseline for the status of ruffed grouse in the BHNF and we encourage continued use of occupancy modeling given its successful use in this study. We recommend continuing drumming surveys between the first and fourth week of May when detection probabilities are highest. Surveys should be completed as close to sunrise as possible (≤ 5 hr after sunrise) and on rain or snow-free days with little or no wind. Further, observers should be rotated between successive surveys to ensure observer experience does not influence detection probability. Maximizing the probability of detecting ruffed grouse will improve the efficiency of monitoring trends in ruffed grouse occupancy in the BHNF.

ACKNOWLEDGMENTS

We thank L. Benkobi, K. Burns, P. Christensen, A. Crosby, R. Crowhurst, S. Deisch, R. Everett, T. Juntti, C. Lehman, C. Mehls, A. Nolan, J. Shulz, C. Stanton, and M. Tarby for their assistance with fieldwork. S. Deisch, H. He, R. King, and M. Larson provided valuable input that greatly improved the quality of the study. We also thank R. Gitzen, F. Thompson, III, D. Turner, B. Collier, D. Stauffer, and one anonymous reviewer for their helpful comments on the manuscript. This research was supported by the United States Forest Service, Rock Mountain Research Station, Rapid City, SD (05-JV-11221609-239), United States Forest Service, Black Hills National Forest, South Dakota Department of Game, Fish, and Parks (grant no.: W-75-R-49, AM4 [under grant amendment no. 171]), and the University of Missouri.

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Associate Editor: Bret A. Collier.