IDENTIFYING PLOTS FOR SURVEYS OF PRAIRIE-CHICKENS IN MINNESOTA

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SUMMARY OF FINDINGS

To explore potential improvements in surveys of greater prairie-chickens (*Tympanuchus cupido pinnatus*) in Minnesota, we developed this study to determine landscape-scale characteristics associated with plots of land occupied by prairie-chicken leks and to evaluate potential within-year sources of variation in the probability of detecting a prairie-chicken lek, if one is present. The study area consisted of nearly the entire range of prairie-chickens in northwestern Minnesota. Observers visited randomly selected Public Land Survey (PLS) sections (~259 ha) 3 times during April and early May of 2005 to detect leks. Confirmatory analyses indicated that wind speed and cloud cover were negatively correlated with the probability of detecting a lek. Road density was positively correlated with the probability of detection, but it was negatively correlated with the probability of a section being occupied by a lek. Exploratory analyses also revealed positive correlations between occupancy and both grass cover as a proportion of area and the area of all cover types considered as habitat and a negative correlation between occupancy and distance to the nearest known lek from the previous year. Comparing only models that included only covariates for which data are available for all plots within prairie-chicken range (i.e., uncorrected GAP data and other Geographic Information System (GIS) based landscape characteristics), models that included covariates measured at the plot scale fit better than those that included covariates measured at a larger landscape scale in the exploratory analysis, but there was no difference in fit in the *a priori* analysis. Approximately 13% of sections in the study area were occupied by a lek, but the precision of the estimated abundance of occupied sections was low ($\hat{Y}$ = 420, SD = 270).

INTRODUCTION

Nearly all methods for monitoring populations of greater prairie-chickens, including those currently employed by the Minnesota Department of Natural Resources (MNDNR), depend upon locating leks, or concentrations of the birds at their arenas for breeding displays (i.e., booming grounds) during spring. Surveying a statistically valid sample of leks requires identifying all areas where leks may occur and then sampling to find a number of plots occupied by active leks. The range of prairie-chickens in Minnesota covers approximately 10,000 km^2, so a major limitation to monitoring leks of prairie-chickens is determining where to survey within that range.

The availability of GIS technology and databases of spatially explicit land cover have made it feasible to use landscape-scale habitat criteria to identify areas where leks may occur. Although land cover associated with prairie-chicken leks in Minnesota and Wisconsin have been quantified during previous studies (Merrill et al. 1999, Niemuth 2000, 2003), interpretation and application of those data are problematic. In particular, the previous studies were based on a case–control sampling design, which does not allow inferences about relative probabilities of occurrence (Keating and Cherry 2004). In addition, they did not select active leks randomly or verify nonuse at the randomly selected control locations.

Inferences about trends in the abundance of grouse throughout the state require statistically valid samples of survey locations from defined areas in which the species may occur. This study builds upon existing knowledge of landscape-scale habitat criteria that may be useful for identifying plots where prairie-chicken leks may occur, thereby dramatically reducing the area needed to be included in monitoring programs. It also serves as a pilot project for a new survey design that may prove to be more efficient than current survey methods for detecting changes in the abundance of prairie-chickens. Results of this study may benefit management programs for prairie-chickens by improving the quality of inferences drawn from spring surveys and developing resource selection functions for using landscape characteristics to estimate the relative probability of an area being occupied by a lek.

OBJECTIVES

- To determine landscape-scale characteristics associated with plots of land occupied by prairie-chicken leks in Minnesota; and
- To evaluate potential within-year sources of variation in the probability of detecting prairie-chicken leks in Minnesota.

METHODS

Study Area

Prairie-chickens occur in 3 distinct ranges in Minnesota. A study area was established in the northwest prairie-chicken range because the northwest range contained the largest population of prairie-chickens, was where the hunting permit areas were, and was the focus of all recent prairie-chicken monitoring efforts by the MNDNR. The study area included the northern 96% of the northwest range as defined by Giudice (2004) based upon land type associations of the Ecological Classification System (Figure 1). The size of the study area was limited only by a maximum distance of 90 km to the southeast of Moorhead, where the southernmost field technicians resided.

Notation

Methods for this study were based on analytical techniques for estimating the probability of site occupancy (MacKenzie et al. 2002). Throughout this report notation follows that of MacKenzie et al. (2002): ψ, probability that a sample plot is occupied by a lek; *p*, probability of detecting a lek within a sample plot, given that the plot is occupied; N, number of sample plots in a study area; T, number of surveys, or distinct sampling intervals during which all plots are visited once; the "hat" character (e.g., $\hat{\psi}$) denotes the estimated value of a quantity; and *c*, the probability of detecting a lek during visits that occur after a lek already has been detected within a plot (i.e., recapture).

Sampling Design

A sampling unit, or plot, was defined as a PLS section, most of which were 1.6- $\times$ 1.6-km squares (i.e., 259 ha = 1 mi^2). In portions of the prairie-chicken range in Minnesota some PLS sections were rectangular and much smaller than 259 ha. Variability in the size of plots was accounted for by the possible inclusion of habitat area within a plot as a covariate for ψ. The size of plots roughly corresponded to home range sizes of prairie-chickens during spring (<400 ha; Robel et al. 1970).

We applied a dual frame sampling design in which samples were drawn from a list frame consisting of plots known to have been occupied by a lek during 2004, and a much larger area frame consisting of the statistical population of plots to which the estimate of occupancy can be inferred (Haines and Pollock 1998). The area frame completely overlapped the list frame, so inferences were based upon the mutually exclusive overlap and nonoverlap domains. Dual frame sampling was appropriate for this study because an area frame was necessary for sample plots to be representative of other plots in the population, and the list frame was useful for focusing adequate sampling effort in plots where leks were known to have occurred recently. The locations of leks, especially those attended by more than a few males, are relatively consistent among years (Schroeder and Braun 1992), which makes them amenable to the use of a list frame.

Data Collection

An observer visited each sample plot once during each of T=3 consecutive biweekly periods from 4 April 2005 until 15 May 2005 (Svedarsky 1983). A visit consisted of a 20-minute interval between 0.5 hours before and 2 hours after sunrise (Cartwright 2000) during which a plot was surveyed with the purpose of detecting the presence of a lek (i.e., ≥2 male prairie-chickens) by sight or sound. The value of time-dependent covariates of *p* (e.g., wind speed, time of day) were recorded during each visit.

The value of all covariates of ψ and some covariates of *p* varied among plots but not among visits (i.e., they varied spatially but not temporally). We measured these landscape characteristics at 2 different spatial scales—within the boundaries of the plot and also within a 1,600-m buffer of the plot centroid. The larger scale roughly corresponded to areas of nesting and brood-rearing, which usually occur within 1,600 m of a lek (Schroeder and Braun 1992, Ryan et al. 1998). For land cover data we used the GAP level 4 database and combined all cover types not likely to be used by prairie-chickens into a single nonhabitat category. Observers corrected the GAP data at the plot scale in the field, thereby creating a third set of land cover covariate data.

Occupancy models often require an assumption that *p* is homogeneous (i.e., does not vary among plots). Using covariates of *p* in the model may ameliorate the negative effects of potential heterogeneity in *p*, but to prevent the sampling design from introducing heterogeneity, each observer visited a different set of plots during each biweekly survey period. Differences among observers in their ability to detect leks, therefore, would not be correlated with specific plots.

Data Analysis

We transformed the value of the covariates of ψ and *p* so they were within the interval [-9.9, 9.9], which precluded problems with numerical optimization that occur occasionally when using a logit link function. We developed sets of 8 and 14 *a priori* models to represent hypotheses about which covariates contributed to variation in *p* and ψ, respectively. Included in the set of models for ψ were 2 supported by previous studies (Table 1; Merrill et al. 1999, Niemuth 2003). We used Program MARK to fit occupancy models to the detection-nondetection survey data (MacKenzie et al. 2002). We used Akaike's Information Criterion adjusted for sample size (AIC_c) to calculate the Akaike weight (w), which is a relative weight of evidence for a model, given the data. We based inferences on parameter estimates averaged over the best models that accounted for ≥95% of the Akaike weights (Burnham and Anderson 2002:150, 162). To estimate uncertainty in $\hat{p}$ and $\hat{\psi}$ given specific values of covariates we calculated limits of 95% confidence intervals on the logit scale then transformed them to the real scale (Neter et al. 1996:603). We combined estimates of $\hat{\psi}$ across sampling domains to estimate the number of plots occupied by prairie-chicken leks in the northwest range of Minnesota (Haines and Pollock 1998). Finally, we conducted an exploratory analysis by fitting models that were not specified *a priori*.

RESULTS AND DISCUSSION

We randomly selected n_{Area}=135 plots from the area frame (N_{Area}=3,137 plots), but 2 were excluded because they were not accessible by passable public roads and were not visited by observers (Figure 1). Inferences, therefore, were limited to portions of the study area that were accessible by public roads during spring. We randomly selected n_{List}=135 plots from the list frame (N_{List}=181 plots), 1 of which was excluded due to inaccessibility. Six of the plots selected from the area frame were also on the list frame, so $n_{nonoverlap}$=127 plots were in the nonoverlap domain (i.e., 127=135–2–6), and $n_{overlap}$=140 plots were in the overlap domain (i.e., 140=135–1+6).

The AIC-best *a priori* model for *p* was the "global" model, which contained all 16 covariates (i.e., 5 for observers, recapture, day of the study, time of day, temperature, wind speed, presence of precipitation, proportion of the sky obscured by clouds, road density, density of interior roads, proportion of suitable land cover types that were visible from roads, and proportion of suitable land cover types that were under snow or temporary water). It accounted for 97% of the AIC weight in the model set for p.

The 4 best *a priori* models for occupancy, which accounted for 93% of the AIC weight, included covariates measured at the plot scale and land cover data that was corrected in the field (Table 2). Although they contained 21–25 parameters, only 6 model-averaged parameter estimates had confidence intervals that did not include 0 (Table 3). Wind speed, cloud cover, road density, and an observer effect were correlated with *p* (Figure 2; $\hat{\bar{p}}$ = 0.45, 95% CI=0.34–0.56). Road density was also correlated with occupancy (Figure 3). No land cover covariates, however, were correlated with occupancy within each sampling frame. In the *a priori* analysis, models fit equally well at both spatial scales when using uncorrected GAP land cover data (Table 2).

The probability of occupancy based on model-averaged *a priori* models was 0.83 (95% CI=0.31–0.98) for plots in the overlap domain (i.e., from the list frame) and 0.09 (95% CI=0.01–0.46) for plots in the nonoverlap domain (i.e., from the area frame but not the list frame). Therefore, $\hat{\psi}$ = 420 (SD=270) plots in the study area were occupied by a lek. The lack of precision of $\hat{\psi}$ was acceptable, given the objectives of the study. The results, however, will be useful for evaluating the level of sampling effort necessary to estimate $\hat{\psi}$ with adequate precision at range-wide scales in the future.

We started the exploratory analysis by simplifying the model for *p* to include only the dominant 4 covariates rather than all 16 and by using combinations of covariates for ψ that may not have been included in the *a priori* set of models. The AIC-best occupancy model then included domain, habitat area, density of all roads, and density of paved roads as covariates for ψ. There was still much model-selection uncertainty, and the combined-1 and disturbance-1 models for ψ were only 2.0 and 3.1 AIC-units away from the best model.

We further refined the exploratory analysis by removing the domain covariate because it appeared to be an excellent discriminator between occupied and unoccupied plots and therefore potentially masking relationships between ψ and more informative landscape characteristics. Using a reduced model for *p* (K=5) and no domain covariate for ψ resulted in 3 models that accounted for 98% of the AIC-weight in the new exploratory model set (Table 4). As in the *a priori* analysis, the best-fitting models included covariates measured at the plot scale and land cover data that was corrected in the field. The model-averaged parameter estimates whose confidence intervals did not include 0 were those for the proportion of the plot covered in grass, distance to the next nearest lek observed the previous year, area of habitat in the plot, and density of roads (Figure 4).

A goal of this project was to be able to predict the probability of occupancy for any or perhaps all plots in the prairie-chicken range. That would require applying an occupancy model that only included covariates that are available for all plots in the range. The sets of models based on uncorrected data for landscape characteristics meet that criterion. Comparing only models that included covariate data that is available for all plots in the range, those that included measurements at the plot scale fit much better than those that included measurements at the landscape scale (Table 4).

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Table 1. *A priori* models for explaining variation in the probability (ψ) of a sample plot being occupied by a prairie-chicken lek in Minnesota during spring of 2005.

Name	Covariates included
Habitat-1	Grass[a], Prairie[a], Sedge[a], Forest[a,b], Crop[a], Edge[c], Tree[d], Lek distance[e]
Habitat-2	Grass, Prairie, Forest, Edge, Lek distance
Habitat-3	Grass, Forest, Lek distance
Habitat-4	Grass
Disturbance-1	Homes[f], Road density, Density of interior roads[g], Density of paved roads[g]
Disturbance-2	Homes, Road density
Combined-1	Grass, Forest, Lek distance, Habitat area, Homes, Road density
Combined-2	Grass, Forest, Lek distance, Homes, Road density
Combined-3	Grass, Forest, Lek distance, Habitat area
Lek distance	Lek distance
Forest	Forest
Habitat area	Habitat area
Niemuth	Grass, Sedge, Forest, Lek distance
Merrill	Forest, Homes

[a] Proportion of area in this cover type.
[b] Forest cover was estimated in the field. This was replaced by the nonhabitat category when we used uncorrected GAP data.
[c] Edge between forest and nonforest cover types or between nonhabitat and all other cover types when we used uncorrected GAP data.
[d] Presence of trees within suitable cover types; not available in the uncorrected GAP data.
[e] Distance from the nearest known lek during the 2004.
[f] Number of occupied human residences counted in the field; not available in the uncorrected GAP data.
[g] These covariates were observed in the field and were not measured for uncorrected data sets.

Table 2. Ranking of the best *a priori* models of occupancy of PLS sections by leks of greater prairie-chickens in northwest Minnesota during spring of 2005. Models with $\Delta AIC_c \geq 12$ are not shown.

LC data source[a]	Spatial scale[b]	Model[c]	*K*[d]	ΔAIC_c[e]	AIC-weight
Corrected	Plot	Disturbance-1	23	0.0	0.524
Corrected	Plot	Combined-1	25	2.1	0.181
Corrected	Plot	Disturbance-2	21	2.5	0.147
Corrected	Plot	Combined-2	24	3.9	0.074
Uncorrected	Plot	Combined-2	23	7.1	0.015
Uncorrected	Landscape	Combined-2	23	7.2	0.014
Uncorrected	Landscape	Disturbance-1	20	7.9	0.010
Uncorrected	Plot	Disturbance-1	20	9.0	0.006
Uncorrected	Plot	Combined-1	24	9.5	0.004
Corrected	Plot	Habitat-2	24	9.8	0.004
Corrected	Plot	Habitat-1	26	10.4	0.003

[a] Source of land cover data was either corrected or uncorrected GAP level 4.
[b] Scale-dependent covariates were measured within PLS sections (Plot) and within 1,600 m of the plot centroid (Landscape).
[c] Models for the probability of occupancy described in Table 1. All models included sampling domain as a covariate and the global model for the probability of detection, p.
[d] *K* = number of parameters, which includes 2 intercept terms—1 for the *p* portion of the model and 1 for the ψ portion.

[e] The difference In AIC_c values between a given model and the best model in the set.

Table 3. Parameter estimates averaged over the best 4 models of the occupancy of sample plots by leks of greater prairie-chickens in Minnesota during spring of 2005 and unconditional confidence intervals on the logit scale.

Probability	Parameter[a]	Estimated value	95% confidence limits	
			Lower	Upper
Detection	Intercept	-2.269	-6.213	1.675
	Observer 1	-0.474	-1.310	0.362
	Observer 2	-0.363	-1.183	0.457
	Observer 3	-0.201	-0.925	0.522
	Observer 4	-0.749	-1.563	0.065
	Observer 5	1.187	0.359	2.015
	Recapture	0.211	-0.562	0.984
	Day	-0.150	-0.424	0.124
	Time	-0.081	-0.638	0.476
	Temperature	-0.028	-0.083	0.026
	Wind speed	-0.885	-1.253	-0.516
	Precipitation	0.106	-0.720	0.932
	Cloud cover	-0.768	-1.438	-0.098
	Road density	0.469	0.044	0.894
	Interior roads	-0.114	-1.223	0.995
	Proportion visible	2.705	-1.318	6.728
	Ground cover	0.388	-5.925	6.701
Occupancy	Intercept	0.180	-2.368	2.728
	Overlap domain	3.861	2.420	5.302
	Homes	-0.511	-3.793	2.772
	Road density	-1.373	-2.289	-0.456
	Paved roads	-1.062	-2.848	0.725
	Grass	0.276	-0.722	1.273
	Forest	0.259	-1.681	2.200
	Lek distance	-0.349	-1.577	0.878
	Habitat area	0.221	-0.556	0.998

[a] Parameter names for models for *p*, the probability of detection, are described in the text; parameter names for models for ψ , the probability of occupancy, are explained in Table 1.

Table 4. Ranking of the best exploratory models of occupancy of PLS sections by leks of greater prairie-chickens in northwest Minnesota during spring of 2005. Models with $\Delta AIC_c \geq 27$ are not shown.

LC data source[a]	Spatial scale[b]	Model[c]	*K*[d]	ΔAIC_c[e]	AIC-weight
Corrected	Plot	Grass+Lek distance+Habitat area+Road density	10	0.0	0.432
Corrected	Plot	Grass+Lek distance+Habitat area+Road density +Density of paved roads[f]	11	0.4	0.346
Corrected	Plot	Combined-1	12	1.5	0.206
Corrected	Plot	Combined-2	11	6.6	0.016
Uncorrected	Plot	Combined-2	10	14.9	<0.001
Uncorrected	Plot	Grass+Lek distance+Habitat area+Road density	10	16.8	<0.001
Uncorrected	Plot	Combined-1	11	16.9	<0.001
Corrected	Plot	Combined-3	10	17.7	<0.001
Corrected	Plot	Habitat-1	14	17.9	<0.001
Corrected	Plot	Habitat-2	11	18.3	<0.001
Corrected	Plot	Habitat-3	9	18.4	<0.001
Uncorrected	Landscape	Combined-2	10	19.7	<0.001
Corrected	Plot	Niemuth	10	20.0	<0.001
Uncorrected	Landscape	Grass+Lek distance+Habitat area+Road density	10	20.1	<0.001
Uncorrected	Landscape	Habitat-2	11	26.9	<0.001

[a] Source of land cover data was either corrected or uncorrected GAP level 4.
[b] Scale-dependent covariates were measured within PLS sections (Plot) and within 1,600 m of the plot centroid (Landscape).
[c] Models for the probability of occupancy described in Table 1. All models excluded sampling domain as a covariate and the model for the probability of detection, p, included wind speed, cloud cover, road density, and 1 observer effect.
[d] *K* = number of parameters, which includes 2 intercept terms—1 for the *p* portion of the model and 1 for the ψ portion.
[e] The difference In AIC_c values between a given model and the best model in the set.
[f] This covariate was observed in the field and was not measured for uncorrected data sets.

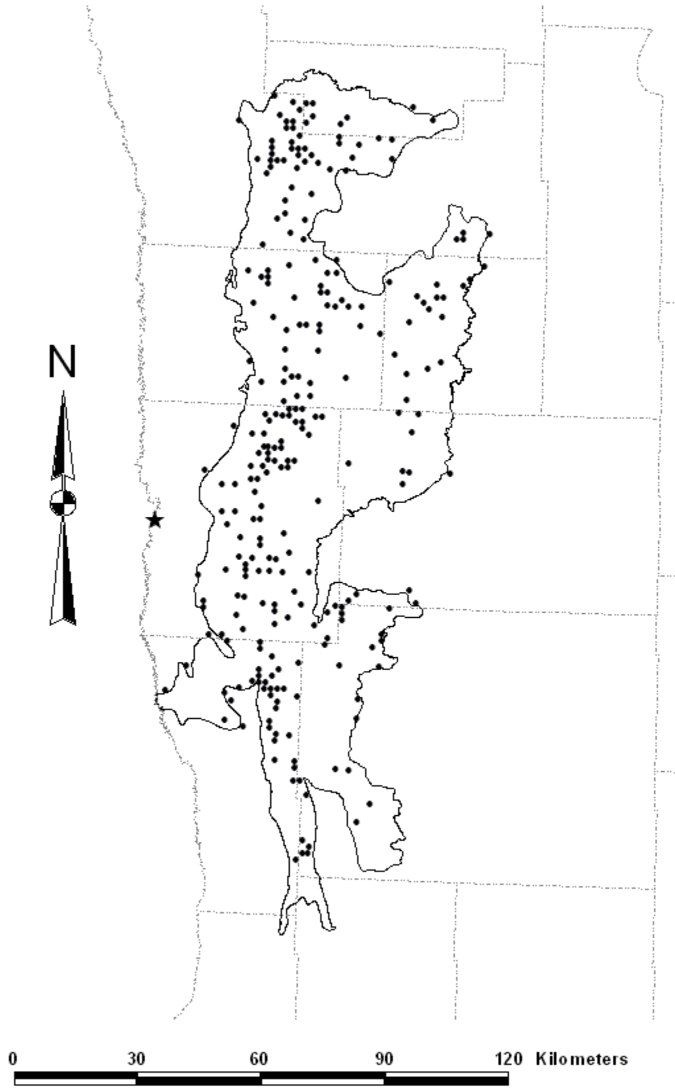

Figure 1. The northwest prairie-chicken range based on land type associations of the Ecological Classification System (solid line) relative to county boundaries (dashed lines) in western Minnesota. Sample plots (dots) were not selected from areas >90 km southeast of Moorhead (star).

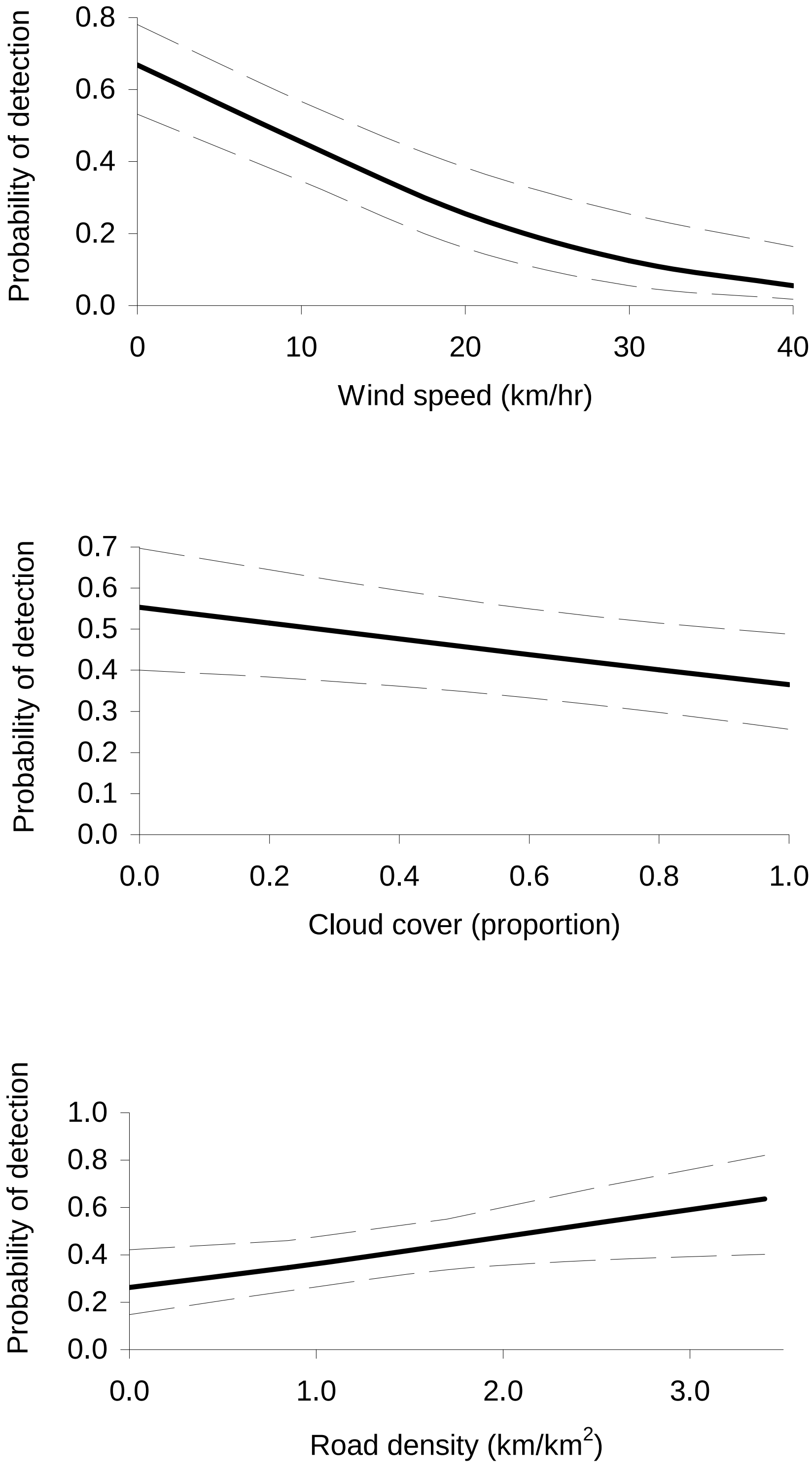

Figure 2. Model-averaged probabilities (and 95% confidence intervals) of detecting a prairie-chicken lek in sample plots in Minnesota during spring of 2005 over the range of observed values of 3 selected model parameters based on *a priori* models.

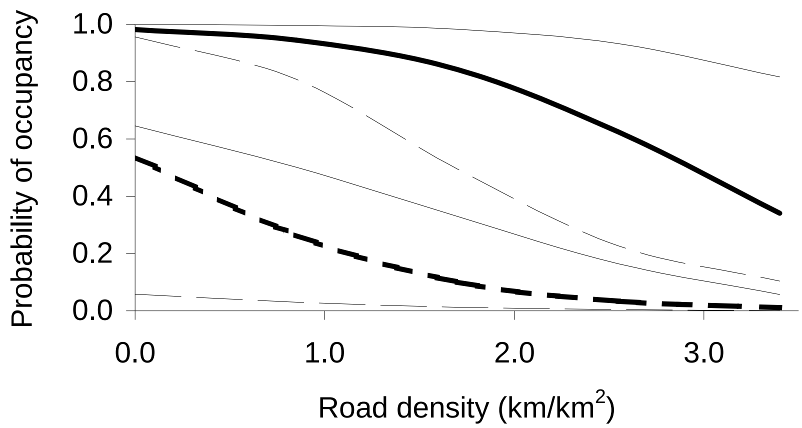

Figure 3. Model-averaged probabilities (heavy lines) and 95% confidence intervals (light lines) of a sample plot in Minnesota being occupied by a prairie-chicken lek during spring of 2005 over the observed range of road densities in the overlap domain (i.e., plots known to have contained a lek during 2004; solid lines) and nonoverlap domain (i.e., all other plots in the study area; dashed lines) based on *a priori* models.

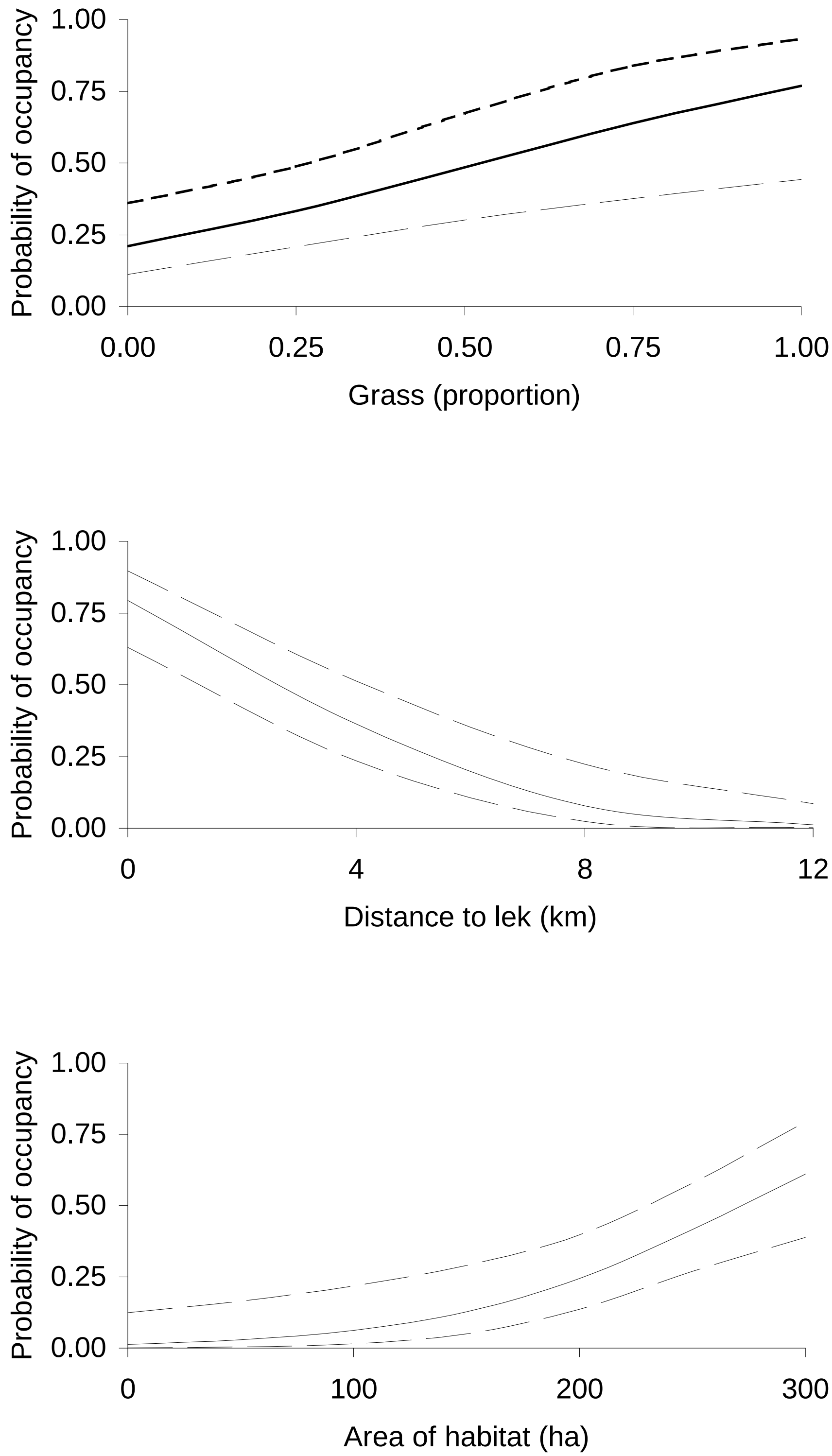

Figure 4. Model-averaged probabilities (and 95% confidence intervals) of detecting a prairie-chicken lek in sample plots in Minnesota during spring of 2005 over the range of observed values of 3 selected model parameters based on an exploratory analysis.