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Grassland Nesting Birds and Visual Obstruction Measurements in Western Kansas on Smoky Valley Ranch

Connor J. Champney
Fort Hays State University, connor.champney@gmail.com

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Connor Champney

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Approved ____________________
Major Professor

Approved ____________________
Graduate Dean

This thesis for

The Master of Science Degree

by

Connor Champney

has been approved by

Committee Member_[signature]_ Date_7/12/2023_
Dr. Medhavi Ambardar

Committee Member_[signature]_ Date_5/18/2023_
Dr. Mitchell Greer

Committee Member_[signature]_ Date_5 June 2023_
Dr. Robert Channell

Committee Member_[signature]_ Date_5/19/2023_
Matthew Bain

Chair, Department of Biological Sciences _[signature]_ Date 6/12/23
Dr. Tara Phelps-Durr

PREFACE

This thesis is written in the style of the Kansas Ornithological Society Bulletin. Keywords: Kansas, mixed-grass, shortgrass, grazing, grassland birds, VOR, visual obstruction, point-count survey, Horned Lark, Grasshopper Sparrow, Western Meadowlark, Mourning Dove, gdistsamp, unmarkedframeGDS

ABSTRACT

North American grassland declines and increasing changes in land use patterns have revived the importance of studying grasslands and their inhabitants. Grassland breeding bird populations are declining rapidly, and conservation efforts are ramping up. Smoky Valley Ranch (SVR) owned by The Nature Conservancy (TNC) is in Logan County, Kansas. Surrounding private land is characteristically comprised of row crops, livestock agriculture, Conservation Reserve Program (CRP), and a few patches of native and restored prairie. The study of obligate grassland birds utilizing this area during the breeding season is essential to the proliferation of grassland bird nesting habitat in western, Kansas. The goal of this study is to characterize species specific abundance based on visual obstruction readings and prairie dog occurrence. Additional covariates such as wind speed, grazing rest, minutes since sunrise, and visual obstruction are measured against detection probability when detection key function is not "uniform." Data was collected using hierarchical distance sampling (HDS) methods to aid in alleviating nondetection bias in point counts. Data collection was collected through 60-point count stations and 300 Robel points, measuring avian abundance, and visual obstruction, respectively. This study bolsters the knowledge base of grassland nesting birds and their habitat usage during the breeding season in western, Kansas. With climate change concerns rising, knowledge of obligate grassland birds and their habitat preferences is an essential aspect of land management in the short to mixed grass prairie.

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INTRODUCTION

Grassland bird populations have declined substantially in North America over the last 40 years (Hill et al. 2014). According to the North American Breeding Bird Survey, 74% of farmland and grassland associated species have declined from 1966 to 2013 (Grand et al. 2019) indicating that grassland birds are declining more rapidly than any other group of birds in North America (West et al. 2016). These declines are attributed to inadequate management, fragmentation (Johnson and Igl 2001), altered land use, habitat loss, and habitat degradation (Hill et al. 2014, West et al. 2016) . Pesticide use and agricultural intensification have also impacted populations in the U.S. and Northern Europe (Mineau and Whiteside 2013).

Grasslands provide habitat for a range of organisms at all taxonomic levels and their importance on a local, regional, and global scale is highly underappreciated (Bengtsson et al. 2019). Overall grassland ecosystem biodiversity is important from a conservation perspective because grasslands provide necessary habitat for numerous organisms to survive. Grasslands also provide essential ecosystem services such as carbon sequestration, water supply and flow regulation, erosion control, and pollinator habitat (Bengtsson et al. 2019). Habitat connectivity is an important part of migration and movement patterns of local species and continuing declines in grassland bird populations highlights the importance of habitat connectivity in the US (West et al. 2016). Measuring these declines is also an essential part in understanding the ecological relationship occurring between grassland birds and their habitat. Certain animal abundance estimation methods can be expensive and time-consuming when applied to large areas (Neubauer and Sikora 2020) making methods such as point-count surveys more desirable. Point count surveys also have ways to account for detection probability in hierarchical distance sampling

(HDS) methods. Additional covariate effects on both abundance and detection can more easily be modeled with HDS as well.

Point count surveys are primarily used to monitor population changes in breeding land birds (Ralph et al. 1993). Many aspects of population ecology can be measured by using point counts, such as yearly changes in a population at a fixed point, species composition differences between different habitats, and overall abundance patterns of a species (Ralph et al. 1993). The point count survey method involves an observer at a fixed location recording all birds seen or heard at a fixed or unlimited distance. Some point counts are visited once, and others can be revisited numerous times to improve upon the dataset. There are some issues with point count methods such as differences in climate as well as ambient noise occurring during surveys. Auditory detections have been found to make up over 50% (Simons et al. 2007) of observations in suburban landscapes, tropical forests, and closed canopy deciduous forests. Although the grasslands of western Kansas are radically different from forested areas, natural ambient noise from wind, prairie dogs, or droning livestock are still present and can affect surveys. Global climate change could also affect long-term studies using point counts. As seasons shift, there is evidence that birds are breeding earlier in the season (Simons et al. 2007). Earlier breeding results from males calling earlier in the season, which could dramatically reduce abundance counts conducted in the same time frame each year (Simons et al. 2007). Other potential issues associated with point counts is observer variation (Pacifici et al. 2008) and the affect an observer has on detection probabilities. A different observer from year to year could lead to further considerations when analyzing census data over a long-term study. Point count surveys also require preconceived knowledge of local species, and the observer must possess a mental index of songs, calls, and plumage to adequately utilize this method. According to (Ralph et al. 1993), each individual should be recorded as being within a 50 m radius of the observer or outside a 50 m radius of the observer. This recommendation is supported by the findings of (Diefenbach et al. 2003) who discovered 60% of birds outside a 50 m radius were missed during a fixed-width transect survey. A way to combat missed detections is to use HDS which intrinsically includes methods of estimating detection probability.

Hierarchical distance sampling is considered one of the most widely used methods for estimating abundance (Sillett et al. 2012). It involves recording the perpendicular distance of an individual to the observer in discrete distance classes (Sollmann et al. 2015) therefore allowing detection probability to be measured without mark, recapture methods. Distance sampling assumes detection probability declines as distance from the observer increases allowing for abundance and density estimates while accounting for nondetection bias (Royle et al. 2004). This relationship between distance and detection probability is modeled along with covariates on detection and abundance in HDS methods (Royle et al. 2004, Sollmann et al. 2015). This creates a more inclusive modeling framework different from those without the ability to model covariates on abundance (Royle 2004). Hierarchical distance sampling methods are extended to open population models when surveys are repeated over a specified number (T) of primary periods which are synonymous to revisits within a single season (Sollmann et al. 2015). This open population model is important for acknowledging emigration and immigration between survey periods due to the mobility of the focal taxa.

Smoky Valley Ranch (SVR), a grassland conservation area and working cattle ranch in western Kansas, is a good representative of native and reseeded grasslands in the area. SVR has implemented an active management strategy to maintain heterogeneity of both vegetation structure and vegetative species composition, while diligently monitoring the landscape to prevent overgrazing. SVR managers focus on improving range conditions and forage production through the active management of patch burn rotational grazing using calf-cow cattle leases and a Nature Conservancy (TNC) bison herd. Grazing is a major factor in rangeland systems since historically, the Great Plains were occupied by massive herds of Bison (*Bison bison)* which have now been replaced by domesticated cattle (*Bos taurus*) (Suttie et al. 2005). Bison played a major role in the condition and appearance of the entire Great Plains, and management strategies at SVR are focused on representing the full range of historic spatial and temporal ecological variability through the use of light to moderate stocking rates and rotational grazing (Bain 2016). An additional factor implemented on the study site is occasional prescribed fire. The fire return interval used by SVR is seven to nine years and SVR uses prescribed fire as a management tool for improving black-tailed prairie dog (*Cynomys ludovicianus*) densities and distribution, improving prairie chicken habitat (*Tympanuchus pinnatus* and *Tympanuchus pallidicinctus)*, managing against cool-season grasses, and manipulating the landscape to maintain plant community diversity and structure goals (Bain 2016). These strategies of management are important for the scope of this study.

The objective of this study was to determine abundance covariate effects and detection covariate effects on grassland bird species at Smoky Valley Ranch in the short to mixed grass prairie of western, Kansas. Abundance covariates such as visual obstruction of nests and other areas by vegetation as well as black-tailed prairie dog presence have been shown to influence avian species composition and site specific selection (Augustine and Baker 2013). Two of the four focal species in this study, Horned Lark (*Eremophila alpestris*) and Mourning Dove (*Zenaida macroura*) have been found in the Northern Great Plains, to be more abundant when prairie dogs are present (Augustine and Baker 2013). An additional focal species, Grasshopper

Sparrow (*Ammodramus savannarum*) has been found to be more abundant when prairie dogs were absent (Augustine and Baker 2013). Visual obstruction has also been found to be a determining factor in breeding site selection of Western Meadowlark (*Sturnella neglecta*) (Dieni and Jones 2003). Due to deliberate habitat selection of grassland birds in this region, four species were observed with high enough frequency during point-count surveys to develop statistical models. These species were the Horned Lark, Grasshopper Sparrow, Western Meadowlark and Mourning Dove. We hypothesized that species would have a unique preference for visual obstruction and prairie dog occurrence based on nesting and habitat preferences of each specific species (Augustine and Baker 2013).

Preferred breeding habitat varies by species. Grasshopper Sparrows prefer open grasslands and prairies with patches of bare ground, and they select for different components of vegetation depending on the ecosystem (Ruth 2015). This vegetation selection is a result of being a primarily ground foraging species (Royle et al. 2004, Vickery 2020). Studies have also shown Grasshopper Sparrows prefer native grasslands rather than crop fields in production or fallow within the Mixed-grass prairie (Ruth 2015). The Grasshopper Sparrow's breeding range is vast in the United States and encompasses all of Kansas (Vickery 2020). The Western Meadowlark avoids breeding in areas with high forb cover and nests in areas with greater visual obstruction and vegetation density and height (Dieni and Jones 2003). Western Meadowlarks are found most often in native grasslands and areas converted from cropland to a more native perennial mix (Davis and Lanyon 2020). The Western Meadowlark has an extensive range west of the Mississippi River and can be found during the breeding season and year-round in the western two-thirds of Kansas (Davis and Lanyon 2020). The Horned Lark prefers breeding areas with short, sparse vegetation and some patches of bare soil (Augustine and Derner 2015, Hartman and

Oring 2003) and have been considered one of the only shortgrass specific species (Samson and Knopf 1996). The Horned Lark is capable of breeding throughout all of North America with some exceptions in coastal regions, and no known occurrences in portions of central Canada (Beason 2020). The Mourning Dove is a habitat generalist which has benefited from anthropogenic changes to North America (Otis et al. 2020). Mourning Doves prefer open habitats and typically avoid heavily forested areas and wetlands (Otis et al. 2020). As a partial migrant, most migration occurs in breeding populations at northern latitudes while populations in more southern latitudes remain year-round residents (Otis et al. 2020). These four species were the most abundant throughout my study area and are candidates for future monitoring of population growth and decline.

METHODS

Field site establishment

This study took place on Smoky Valley Ranch (SVR) owned by The Nature Conservancy (TNC). TNC is a non-profit organization focused on conserving the lands and water upon which all life depends for survival. Smoky Valley Ranch is an 18,000-acre ranch positioned in Logan County, Kansas within the Smoky Hill River Breaks Ecological Focus Area in the transitional zone between the short and mixed grass prairies (M.R. Rohweder n.d.). This short grass prairie and Conservation Reserve Program (CRP) region is characterized by a presence of short grasses such as buffalograss (*Bouteloua dactyloides* [Nutt.] J.T. Columbus) and blue grama (*Bouteloua gracilis* [Willd. ex Kunth] Lag ex Griffiths), and mid-grasses such as sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), little bluestem *(Schizachyrium scoparium* [Michx.] Nash.), sand dropseed (*Sporobolus cryptandrus* [Torr.] A. Gray), and western wheatgrass (*Pascopyrum smithii* P.A. Love) (Schindler et al. 2020).

Field sites were established by SVR managers in 2015 as part of a long-term monitoring project studying avifauna and their presence based on visual obstruction measurements. Transects were established in the best available areas to allow for a continuous 2000 m transect. Ecological site is not used as a treatment, but rather a method of narrowing the focus of this study to include areas of mixed-grass vegetation with sparse short-grass species interspersed. Selected sites for this project included those within the loamy upland, limy upland, and chalk flats ecological sites. Loamy upland is dominated by blue grama, buffalograss, western wheatgrass, sand dropseed, and where prairie dogs are present, purple three awn (*Aristida purpurea* Nutt.) (Bain 2016). Limy upland is dominated by blue grama, buffalograss, western wheatgrass, sand dropseed, sideoats, and little bluestem (Bain 2016). Chalk flats are dominated by little bluestem, sideoats grama, big bluestem (*Andropogon gerardii* Vitman), tall dropseed (*Sporobolus compositus* [Poir.] Merr.), Indiangrass (*Sorghastrum nutans* [L.] Nash), switchgrass (*Panicum virgatum* L.), and an abundance of forbs (Bain 2016). The loamy upland ecological site contained two transects, the limy upland contained three transects, and one transect was split, having five point count stations within the limy upland and five point count stations within the chalk flat ecological sites. Ecological sites excluded from this research were riparian and sandy lowland habitat which are not within the scope of this study because the vegetation does not characterize a uniform grassland habitat.

As a managed area, grazing occurred on 40 of 60 sites during at least one of the survey periods in my study. The 20 sites which did not experience any grazing during a survey period, had livestock grazing implemented earlier in the growing season. These grazing prescriptions were of varying lengths at a light to moderate stocking rate. Although no sites experienced prescribed fire in 2022, patch burning occurred adjacent to transects in 2021. Potential influences of patch burning were not measured. Strategies of management beyond the ones discussed thus far are less important for this study.

Avian Surveys

I conducted avian surveys from 1 June 2021 through 2 July 2021, and 31 May 2022 through 29 June 2022. The surveys I conducted in 2021 were used as a pilot study to test and guide methodology; results for this year are not reported in this study. Results reported in my study are from 2022 only. These surveys were conducted during this time period because it constituted the breeding period of grassland birds in this area. Surveys took place between sunrise and 1030 hours with wind no more than 32.2 kilometers per hour and visibility at least out to 75 m for purpose of detectability. These parameters were adapted from the SVR protocol and allows for the greatest abundance of grassland bird pairs utilizing the area for breeding. There were six transects with 10 point-count stations per transect, amounting to 60 point-count stations in total for this study. Each point along the transect was 200 m (±25 m) apart per SVR protocol which is an adapted version of the extensive point count method (Ralph et al. 1993). At each station, I listened and watched for birds for five minutes using binoculars and a range finder to assess the distance of each bird from the observation point in meters. Initially, the protocol involved recording species that were seen or heard only within a 50 m radius of the station. Visible evidence of bird presence outside the 50 m radius became too significant to ignore after two visits per transect in 2021. On 15 June 2021, I officially started recording birds in two distance classes. Between the observer and 50 m or between 50 m and 75 m to conform to distance sampling methods necessary for analysis and prevent any crossover between points (Ralph et al. 1993, Royle et al. 2004). After the first three minutes of observation, any additional individuals I observed were recorded separately for two more minutes to assess the impact of this additional time on detectability. Data from all five minutes were used in my analyses. This method also allows for comparison with Breeding Bird Survey data, and continued usage by SVR in their monitoring (Ralph et al. 1993). Flyovers during surveys and flushed species, found between each point were recorded separately (Ralph et al. 1993) and not used during analyses of this research. Birds flushed within 50 m of a point count station during arrival were recorded as seen in the first three minutes. Birds flushed while leaving, were recorded as seen within the final two minutes of the survey period. Each transect was surveyed six times in 2021 and four times in 2022. Two points in transect five were removed due to a sudden change in wind speed between point count surveys, resulting in a violation of the wind speed parameters. Only three total visits were completed to these points and this made them ineligible for generalized distance sampling methods in R. All data and methods henceforth reflect 2022 surveys.

Vegetation Surveys

I conducted vegetation surveys within one day of each point count survey in 2022. This was done to minimize the amount of time vegetation could grow between avian surveys and vegetation surveys. Five visual obstruction readings (VOR) were taken using a Robel pole, at each point count station. Robel readings were taken at the center point each time and 25 m from center in each selected direction, depending on the visit number. A measure of the first 100% visually obstructed cm on the pole and the associated vegetative species was taken, as well as the tallest cm touched and its associated species. These VOR were taken four meters from the Robel pole at a height of one meter to provide data on vegetation visual obstruction and height (Robel et al. 1970). A total of five individual Robel points per station were also associated with estimated directional measurements based on landmarks and my knowledge of the cardinal directions in the field, rather than a compass (Fig. 1). At each individual Robel point, four readings were taken in the cardinal directions adding up to 20 total measurements per station and 200 total measurements per transect. There were four vegetation surveys to correspond with four avian surveys at each point-count station.

Statistical Analyses

I used the generalized distance sampling model of (Royle et al. 2004, Chandler et al. 2011), implemented in R (R Core Team 2021) with the package Unmarked (gdistsamp) (Chandler et al. 2021). Using the gdistsamp modeling function requires a data frame organization of unmarkedFrameGDS. This generalized distance sampling method was selected to account for temporary emigration during the 5-minute survey periods (Buckland et al. 2001, Chandler et al.

2011). This model process accounts for covariate effects on abundance and detection rates which decreases the likelihood of biased estimators (Royle et al. 2004).

After initial data collection and computerized input, I averaged the vegetation data. As mentioned above, at each point count station, there were five vegetation readings. Each reading has an associated cardinal direction reading to make up all 20 vegetation readings per point count station. For this analysis, the mean of the cardinal directions was calculated, then the mean of the five vegetation points was calculated. This created one mean VOR reading per point count station, per visit. For avian data management, I divided overall avian abundance into species specific abundance tables. Each table was manually populated with zeros when that species was not observed at a point count station for all four visits. Field data sheets did not explicitly acknowledge absence of any species, only abundance of species that were present.

Additional data collected during surveys included prairie dog presence or absence, wind speed in 8.2 kilometer per hour ordinal classes from 0-32.2 kilometers per hour, time since sunrise in minutes, and days since last livestock grazing occurred. VOR and prairie dog presence were used as covariates of abundance while wind speed, time since sunrise, and days since grazing were measured as covariates affecting detection. VOR was also analyzed against detection due to the biological hypothesis that VOR affects both habitat selection (abundance) and probability of seeing or hearing a species (detection) (Table 1). When I specify prairie dogs as present at sites, it is an indication of active burrows within a prairie dog colony. Prairie dog presence does not necessarily mean the prairie dogs were active and spotted during the survey. Typically, observer effect would have caused a retreat of prairie dogs and spotting them during an avian survey may not have occurred although evidence of an active prairie dog burrow was clear within the bird point count radius.

I created a correlation matrix table (Table 1.2) with all relevant covariates and the species of interest to assess the data for multicollinearity. This was done to avoid including colinear variables in the analysis, potentially affecting results. Before this correlation matrix was created, vegetation height was removed due to its known correlation with VOR. Thus, Table 1.2 does not include correlation coefficients for vegetation height. Visual obstruction was retained for analyses as this measurement was expected to be a more robust predictor of bird abundance. Once all data were divided by species and filled in with all necessary covariates, data were required to be arranged into a data frame of type unmarkedFrameGDS. This data frame required a matrix of observed data, a data frame of covariates that varied at site level, the number of primary periods (visits), yearly site covariates which is the number of days since the last survey was conducted—a zero was used for the first survey at each point. Other requirements included a vector of distance classes binned into discrete intervals. For this study, there were two distance classes, 0-50 m and 50-75 m. Finally, the type of survey, either point or transect,—in our case point—and the units of the distance bins (meters) were included. All data had the same number of columns as it did primary periods, and a corresponding number of rows to the number of sites, in our case 58. After data were arranged into the proper format, I loaded my data into the unmarkedFrameGDS and continued analysis with gdistsamp.

There are four key detection functions and two distribution mixtures available when using the gdistsamp modeling function. Key detection functions include hazard, half normal, uniform, and exponential. Distribution mixtures include a Poisson distribution and a negative binomial distribution. To assess the best detection function and mixture, the first step in each species analysis was to create a table of null models with no covariates based on an information theoretics approach, AICc which is an adjusted Aikike's information criterion (AIC) for small population sizes (Symonds and Moussalli 2011, Marc J. Mazerolle 2020). The model with a ΔAICc of 0 in the table, was considered the top model (Arnold 2010). The key detection function and distribution mixture of the top model was then used to create species specific models with covariates of interest. For Horned Lark, I specified a key detection function based on the half-normal key function with a negative binomial distribution (Table 2). For Grasshopper Sparrow, Western Meadowlark, and Mourning Dove, I specified a key detection function based on the uniform key function. Modeling of a uniform key detection function does not include variables of interest analyzed against detection probability, thus detection probability was not analyzed for these three species.

Grasshopper Sparrow had a Poisson distribution (Table 3). Western Meadowlark had a negative binomial distribution (Table 4) and Mourning Dove also had a negative binomial distribution (Table 5). Throughout all Horned Lark, Western Meadowlark, and Mourning Dove analyses, a negative binomial distribution was used based on model averaged estimates of the most appropriate mixture and detection functions. Negative binomial distributions are typically selected when data are over dispersed (Zeileis et al. 2008). I understood this and used information theoretics to select the best model. It should be noted that some researchers have found, using a negative binomial distribution may not always be the best answer for explaining overdispersion in data (Kéry et al. 2005).

For my analyses, I created forty-five species-specific a priori models based on my objectives and realistic covariates. After models were created using gdistsamp, I used “aictab” in the package AICcmodavg in R, (Marc J. Mazerolle 2020) to produce information criterion tables for the 45 different models. Model averaged tables produced results for AICc values, Delta AICc (ΔAICc), k, and AICc weights for candidate models. Models with a ΔAICc greater than 2.0 are considered to be less informative and were not considered further (Arnold 2010). The top model (or models) with a ∆AICc, of zero is considered to have the most support for describing the data. These models with a ∆AICc, of 2.0 or less were organized and model averaged using the modavg function with 85% confidence intervals (Arnold 2010, Peterson 2014) to assess biological relevance and avoid variable selection ambivalence. An 85% confidence interval was used to better align with the significance level associated with AIC model selection. This is necessary when making biological inferences based on confidence intervals (Arnold 2010). Parameter type was specified along with the parameter of interest in the model averaged estimates. Due to the use of primary periods in gdistsamp, each visit was analyzed separately. Four main species and four visits, amounts to 16 models which were created and analyzed separately due to the variable distinction made by gdistsamp between visits.

RESULTS

I conducted four surveys at 60 sites counting a total of 449 birds within the point count radius, 183 birds flying over the point count stations, and 94 birds flushed between point count stations for a total of 726 individuals. There were 18 species observed (Table 6), with the most abundant being Horned Lark (50.5% of total) , Grasshopper Sparrow (15.8% of total), Western Meadowlark (14.9% of total), and Mourning Dove (8.4% of total). Additional species detected included, Baltimore Oriole (*Icterus galbula*), Brown-headed Cowbird (*Molothrus ater*), Burrowing Owl (*Athene cunicularia*), Cassin's Sparrow (*Peucaea cassinii*), Cliff Swallow (*Petrochelidon pyrrhonota*), Common Grackle (*Quiscalus quiscula*), Common Nighthawk (*Chordeiles minor*), Eastern Kingbird (*Tyrannus tyrannus*), Killdeer (*Charadrius vociferus*), Lark Sparrow (*Chondestes grammacus*), Lesser-Prairie Chicken (*Tympanuchus pallidicinctus*), Red-winged Blackbird (*Agelaius phoeniceusi)*, Turkey Vulture (*Cathartes aura*), and Western Kingbird (*Tyrannus verticalis*). These species were relatively low in abundance, so my analyses focus on the four most common species and their estimates of abundance with the covariates of interest.

Horned Lark

I model averaged two candidate models from my Horned Lark data set for visit one that had a ΔAICc ≤2 (Table 7). I identified the following covariates of interest from these models: VOR on abundance, time since sunrise, and VOR on detection probability. VOR on abundance (85% CI=-0.18— -0.08) influenced Horned Lark abundance and time since sunrise (85% CI=0—0.01) influenced detection probability of Horned Larks. VOR on detection did not influence detection probability (85% CI= -0.01—0.13). VOR was negatively associated with Horned Lark abundance while time since sunrise had a positive association with detection probability (Table

8). For visit two, I model averaged five candidate models from the Horned Lark data set that had a ΔAICc ≤2 (Table 9). The covariates of interest were VOR on abundance, prairie dog presence, wind speed, days since grazing occurred, time since sunrise, and VOR on detection probability. VOR (85% CI=-0.18— -.0.08) influenced Horned Lark abundance on visit two while time since sunrise (85% CI=0—0.01) and wind speed (85% CI=0.07—0.5) influenced detection probability. Prairie dog presence (85% CI=-0.22—0.76) did not influence abundance and days since grazing (85% CI=-0.01—0.1) and VOR (85% CI=-0.05—0.24) did not influence detection probability. VOR was negatively associated with Horned Lark abundance while wind speed and time since sunrise were positively associated with detection probability (Table 10). For visit three, I model averaged three candidate models from the Horned Lark data set that had a ΔAICc ≤2 (Table 11). I identified the following covariates of interest from these models: VOR on abundance, wind speed, days since grazing occurred, and VOR on detection probability. VOR (85% CI=-0.15— -0.05) influenced Horned Lark abundance on visit three and wind speed (85% CI=0.14—0.67) influenced detection probability. Days since grazing (85% CI=-0.02—0) and VOR on detection (85% CI=-0.01—0.11) did not influence detection probability. VOR was negatively associated with Horned Lark abundance while wind speed was positively associated with detection probability (Table 12). For visit four, I model averaged six candidate models from the Horned Lark data set that had a ΔAICc ≤2 (Table 13). The covariates of interest were VOR on abundance, wind speed, time since sunrise, days since grazing, and VOR on detection probability. VOR (85% CI=-0.18— -0.05) influenced Horned Lark abundance on visit four. Wind speed (85% CI=-0.03—0.45), days since grazing (85% CI=-0.01—0.01), and VOR on detection (85% CI=-0.05—0.16) did not influence detection probability. Time since sunrise

(85% CI=0—0) had no effect on detection probability. VOR was negatively associated with Horned Lark abundance on visit four (Table 14).

Grasshopper Sparrow

I model averaged fifteen candidate models from my Grasshopper Sparrow data set for visit one that had a ΔAICc ≤2 (Table 15). I identified the following covariates of interest from these models: VOR on abundance, and prairie dog presence. Although detection covariates can be found in candidate models, due to a uniform detection function on every visit, there was no change in detection probability. This makes detection covariates unnecessary for these and all Grasshopper Sparrow models. VOR on abundance (85% CI=0.09—0.17) and prairie dog presence (85% CI=-2.96— -0.38) both influenced Grasshopper Sparrow abundance during visit one. VOR was positively associated with Grasshopper Sparrow abundance and prairie dog presence was negatively associated with Grasshopper Sparrow abundance (Table 16). For visit two, I model averaged fifteen candidate models from the Grasshopper Sparrow data set with a ΔAICc ≤2 (Table 17). I identified the following covariates of interest from these models: VOR on abundance, and prairie dog presence. VOR on abundance (85% CI=0.09—0.18) and prairie dog presence (85% CI=-3.05— -0.36) both influenced Grasshopper Sparrow abundance on visit two. VOR was positively associated with Grasshopper Sparrow abundance and prairie dog presence was negatively associated with Grasshopper Sparrow abundance (Table 18). For visit three, I model averaged fifteen candidate models from the Grasshopper Sparrow data set that had a ΔAICc ≤2 (Table 19). The covariates of interest were VOR on abundance and prairie dog presence. VOR on abundance (85% CI=0.1—0.19) and prairie dog presence (85% CI=-2.87— -0.15) both influenced Grasshopper Sparrow abundance on visit three. VOR was positively associated with Grasshopper Sparrow abundance while prairie dog presence was negatively associated with Grasshopper Sparrow abundance (Table 20). For visit four, I model averaged fifteen candidate models from the Grasshopper Sparrow data set that had a ΔAICc ≤2 (Table 21). I identified the following covariates of interest from these models: VOR on abundance and prairie dog presence. VOR on abundance (85% CI=0.11—0.22) and prairie dog presence (85% CI=-2.94— -0.15) both influenced Grasshopper Sparrow abundance on visit four. VOR was positively associated with Grasshopper Sparrow abundance and prairie dog presence was negatively associated with Grasshopper Sparrow abundance (Table 22).

Western Meadowlark

I model averaged thirty candidate models from my Western Meadowlark data set for visit one that had a ΔAICc ≤2 (Table 23). I identified the following covariate of interest: VOR on abundance and prairie dog presence. Due to a detection function based on the uniform key function for all models in my Western Meadowlark data set, covariates affecting detection are ignored for these and all Western Meadowlark models. VOR (85% CI=0.09—0.24) influenced Western Meadowlark abundance on visit one and VOR was positively associated with Western Meadowlark abundance. Prairie dog presence (85% CI=-0.26—1.06) did not influence abundance (Table 24). For visit two, I model averaged thirty candidate models from the Western Meadowlark data set with a ΔAICc ≤2 (Table 25). The covariates of interest were VOR on abundance and prairie dog presence. VOR (85% CI=0.07—0.23) influenced Western Meadowlark abundance and prairie dog presence (85% CI=-0.32—1.06) did not influence abundance. VOR was positively associated with Western Meadowlark abundance (Table 26). For visit three, I model averaged thirty candidate models from the Western Meadowlark data set with a ΔAICc ≤2 (Table 27). The covariates of interest were VOR on abundance and prairie dog presence. VOR (85% CI=0.04—0.2) influenced Western Meadowlark abundance while prairie dog presence (85% CI=-0.12—1.29) did not influence abundance. VOR was positively associated with Western Meadowlark abundance (Table 28). For visit four, I model averaged thirty candidate models from the Western Meadowlark data set with a ΔAICc ≤2 (Table 29). The covariates of interest were once again VOR and prairie dog presence. VOR (85% CI=0.05—0.23) influenced Western Meadowlark abundance while prairie dog presence (85% CI=-0.07—0.23) did not influence abundance. VOR was positively associated with Western Meadowlark abundance (Table 30).

Mourning Dove

I model averaged thirty candidate models from my Mourning Dove data set for visit one that had a ΔAICc ≤2 (Table 31). I identified the following covariates of interest from these models: VOR on abundance and prairie dog presence. Although detection covariates were included in many models of Mourning Dove abundance, due to a uniform detection function, all detection covariates were ignored for each visit. VOR on abundance (85% CI=0.1—0.28) influenced Mourning Dove abundance on visit one, while prairie dog presence (85% CI=-2.53—0.69) did not influence abundance. VOR was positively associated with Mourning Dove abundance (Table 32). For visit two, I model averaged thirty candidate models from the Mourning Dove data set with a ΔAICc ≤2 (Table 33). The covariates of interest from these models were VOR on abundance and prairie dog presence. VOR on abundance (85% CI=0.11—0.32) influenced Mourning Dove abundance, while prairie dog presence (85% CI=-2.47—0.78) did not influence abundance. VOR was positively associated with Mourning Dove abundance (Table 34). For visit three, I model averaged fifteen candidate models from the Mourning Dove data set that had a ΔAICc ≤2 (Table 35). I identified only one covariate of interest from the models: VOR on abundance. VOR on abundance (85% CI=0.21—0.31) influenced Mourning

Dove abundance for visit three (Table 36). VOR was positively associated with abundance. For visit four, I model averaged fifteen candidate models from the Mourning Dove data set with a ΔAICc $\leq$2 (Table 37). There was only one covariate of interest: VOR on abundance. VOR on abundance (85% CI=0.15—0.43) influenced Mourning Dove abundance for visit four. VOR was positively associated with abundance (Table 38).

DISCUSSION

The goal of this study was to analyze abundance and detection covariate effects on grassland bird species at Smoky Valley Ranch (SVR) in western, Kansas. I analyzed bird abundance covariates and detection probability covariates for four bird point count visits during one breeding season in 2022. Sites and some methods were selected based on pre-existing monitoring protocols for avian abundance indices and vegetation visual obstruction readings. I conducted this study to determine if these covariates of interest influenced species specific abundance throughout SVR. Not all covariate effects were analyzed in each model due to differing detection functions.

Grassland nesting birds have unique preferences for breeding habitat. These preferences are based on behavior aimed at increasing breeding opportunities and nesting success based on vegetative species, visual obstruction, prairie dog presence, and the presence of anthropogenic disturbances. My study shows examples of these deliberate decisions. I was able to establish relationships between covariates of interest and their effects on abundance or detection probabilities for the four species of interest, Horned Lark , Grasshopper Sparrow, Western Meadowlark, and Mourning Dove. Grasshopper Sparrow, Western Meadowlark, and Mourning Dove models had a detection function based on a uniform key function which assumes detection probability remains the same, no matter the distance from the observer. Covariate effects on detection probability were not measured for these species as a result.

Abundance and Detection of Focal Species

Horned Larks have been found to exhibit a preference for short, sparse vegetation while also utilizing areas with taller vegetation interspersed (Augustine and Derner 2015). I found that Horned lark abundance was lower at sites with higher VOR values. This is consistent with other research conducted (Hartman and Oring 2003, Henderson and Davis 2014, Augustine and Derner 2015) examining habitat characteristics and site specific selection for abundance, breeding, and nesting. Horned Larks appear to prefer areas with less visual obstruction. At visit one, time since sunrise had a positive association with Horned Lark abundance, meaning Horned Lark detection probability increased with increasing time since sunrise. Detection probability for most species has been shown to decrease with increasing time since sunrise (Farnsworth et al. 2002, Marques et al. 2007, Lituma and Buehler 2016). For visit two, both time since sunrise and wind speed were positively associated with Horned Lark abundance. This means again, detection probability increased with increasing time since sunrise and for visit two, higher wind speeds increased the likelihood of detecting Horned Larks present within the point count radius. This relationship between Horned Lark detection probability and time since sunrise appears to be a novel finding for the Horned Lark. Most literature about Horned Larks does not mention time since sunrise and therefore has not explored this potential pattern. For visit three wind speed was again positively associated with Horned Lark detection probability, meaning higher wind speeds contributed to higher likelihood of detecting Horned Larks. It is possible that as wind speeds increased, calling birds became less audible and all survey efforts became focused on visually searching out individuals during the survey period rather than listening and searching. This could have led to more individuals found during those times. In previous literature, wind speed has been found to have a negative correlation with Horned Lark presence (Robbins 1981). Wind speed was also found to decrease detection probability downwind of an observer and lead to a biased observation radius (Rigby and Johnson 2019). Given the negative relationship between Horned Lark abundance and VOR, it is possible that wind speed, may not have as much of an effect on Horned Lark detection when both visual and auditory detection methods are applicable and employed by observers. Smaller VOR would mean shorter vegetation with additional shortgrass patches where individuals could be observed foraging easier. During visit four, no covariates influenced detection probability. Although prairie dog presence did not have an effect on Horned Lark abundance, research has found Horned Lark abundance to differ depending on prairie dog presence (Augustine and Baker 2013, Ray et al. 2015). Further research could be conducted to better establish a relationship between prairie dogs and Horned Larks.

For Grasshopper Sparrow, VOR and prairie dog presence both influenced abundance. VOR was positively associated with Grasshopper Sparrow abundance. Therefore, Grasshopper Sparrows appeared to select for areas with high visual obstruction. This is expected from previous studies examining habitat selection where Grasshopper Sparrows were found to select for large patches of tall dense grasses (Henderson and Davis 2014, Augustine and Derner 2015) with patches of bare ground interspersed. There is some literature (Sutter and Ritchison 2005) suggesting Grasshopper Sparrows prefer areas of "shorter" vegetation in Kentucky (Sutter and Ritchison 2005), with more patches of bare ground. "Shorter" vegetation was not specifically defined or identified with any data to assess a potential comparison to the shortgrass and mixed-grass prairie of western Kansas.

Prairie dog presence was negatively associated with Grasshopper Sparrow abundance. When prairie dogs were present, Grasshopper Sparrow abundance was lower. This is consistent with previous research (Winter et al. 2003, Augustine and Baker 2013, Ray et al. 2015). Diet could easily be a driving force in determining relationships with prairie dog presence and would be worth researching in the future. Prairie dog presence has more implications than a simple interaction between a prairie dog and a bird species. Prairie dogs are considered keystone species and due to their burrowing and grazing contributions, they create a unique and isolated spot of distinct communities of plants and animals which can differ markedly from the surrounding landscape (Winter et al. 2003). Additional research specifically looking at avian communities on prairie dog colonies versus off prairie dog colonies would be valuable information to add to the index of grassland bird information.

In Western Meadowlark models, for all four visits, VOR was positively associated with Western Meadowlark abundance. This means throughout the survey season, Western Meadowlarks were more abundant in areas with more visual obstruction. Western Meadowlarks have been found to nest in areas with greater VOR, as well as greater vertical vegetation density and height (Dieni and Jones 2003). They also tend to prefer areas with good grass and litter cover (Davis and Lanyon 2020). Although nest site selection was not part of my research, it can be assumed that nesting was occurring during the breeding season in areas where I observed individuals calling and perching. Related research has also found and suggested, habitat for Western Meadowlark and other native grassland birds should be managed for taller more dense vegetation (Augustine and Derner 2015) which is synonymous to greater VOR. Height and density are relative when specific measurements are not suggested. Therefore, it seems pertinent to mention researchers in Minnesota, found pastures with light to moderate grazing and hayfields to be more suitable for breeding and nesting than tall dense and untouched CRP fields (Haroldson et al. 2006). There is a threshold where density and grass height would become unsuitable for Western Meadowlark breeding. In western Kansas, with a light to moderate stocking rate and rotational grazing, Western Meadowlarks appear to show an affinity for areas where there is more visual obstruction.

Prairie dog presence was not related to Western Meadowlark abundance during any of the visits. Western Meadowlarks have been found to exhibit a relationship with prairie dogs in past research (Winter et al. 2003, Ray et al. 2015) and this relationship, although not present in my research, would still be valuable to collect further data on. Without directly measuring abundance at multiple sites on and off prairie dog colonies, there is not enough information or data present in my research to make a generalization that Western Meadowlark abundance does not have a relationship with prairie dog presence in western, Kansas.

For Mourning Dove models VOR was positively associated with Mourning Dove abundance at all four visits. This means whenever VOR was greater, Mourning Dove abundance was also greater. Although Mourning Doves are considered habitat generalists, (Otis et al. 2020) there have been studies conducted to better understand nesting and breeding habitat. In one study on Conservation Reserve Program (CRP) fields and grassland bird nesting, as it relates to grazing disturbance, Mourning Doves were found to nest more frequently in CRP fields with newer growth and less grass cover, as well as more bare ground (Kraus et al. 2022). As a widely distributed species that nests and forages primarily on the ground Mourning Doves need shorter, less dense areas withing their breeding habitat. One researcher noted that Mourning Doves nested on bare ground areas with thin litter layers in grasslands (Kraus et al. 2022) and others have acknowledged the benefit of bare ground when it comes to breeding habitat (Thomas 2014). For visit one and two, although prairie dog presence was a covariate of interest, it did not influence Mourning Dove abundance. Some research has found Mourning Doves to be more abundant when prairie dogs were present compared to when prairie dogs were absent in the mixed-grass prairie of South Dakota (Ray et al. 2015). Research conducted in southeast Colorado and southwest Kansas found Mourning Dove abundance to be higher on prairie dog colonies (Winter et al. 2003). Without more deliberately measuring prairie dog influence on avian abundance at a broader scale, generalizations about relationships existing between prairie dogs and grassland birds cannot be made.

There are patterns of habitat selection exhibited by grassland nesting birds. Depending on nesting and foraging requirements, species can be found preferring areas with higher or lower visual obstruction readings. VOR was positively associated with Grasshopper Sparrow, Western Meadowlark, and Mourning Dove abundance. VOR was negatively associated with Horned Lark abundance. Greater visual obstruction means there is denser and, in some cases, taller vegetation present at a site. Visual obstruction is a strong indicator of the amount of vegetation present (Robel et al. 1970) and grassland birds have been shown to occur in greater abundance at sites that support their specific preferences (Dieni and Jones 2003, Augustine and Derner 2015, Kraus et al. 2022). Identifying a relationship more substantial than a positive or negative association would be greatly beneficial to the overall conservation of these four grassland nesting birds as well as additional species of interest in the future. The results I found in my study can be used as a rough guide for managing grasslands where these species are present during the breeding season. Future research should be focused on finding a more definitive relationship with quantifiable numbers that can be used to guide management using the tools available (i.e., fire, grazing, and rest/deferment).

Prairie dog presence has been found (Augustine and Baker 2013, Ray et al. 2015) in multiple studies to have an effect on grassland bird abundance. Prairie dog presence was found to influence abundance of one of four species in my study, Grasshopper Sparrow. There was a negative relationship and this is consistent with past research (Winter et al. 2003, Augustine and Baker 2013, Ray et al. 2015). Although Horned Lark, Western Meadowlark, and Mourning Dove abundance was not found to be affected by prairie dog presence, this could be due to a lack of data. Future researchers interested in prairie dog presence and grassland bird associations should conduct more extensive surveys on and off prairie dog colonies to allow for a more robust data set from which more definitive conclusions can be drawn.

Low Abundance Species

Bird species that were not observed frequently enough to warrant statistical tests were Baltimore Oriole (*Icterus galbula*), Brown-headed Cowbird (*Molothrus ater*), Burrowing Owl (*Athene cunicularia*), Cassin's Sparrow (*Peucaea cassinii*), Cliff Swallow (*Petrochelidon pyrrhonota*), Common Grackle (*Quiscalus quiscula*), Common Nighthawk (*Chordeiles minor*), Eastern Kingbird (*Tyrannus tyrannus*), Killdeer (*Charadrius vociferus*), Lark Sparrow (*Chondestes grammacus*), Lesser-Prairie Chicken (*Tympanuchus pallidicinctus*), Red-winged Blackbird (*Agelaius phoeniceusi)*, Turkey Vulture (*Cathartes aura*), and Western Kingbird (*Tyrannus verticalis*).

Cassin's Sparrows were spotted performing an aerial call known as skylarking (Kathleen Groschupf 1983) from an exposed perch. Habitat surveyed in this study may not reflect the ideal habitat and VOR for Cassin's Sparrow nesting and breeding. Cliff Swallows were spotted at various sites, but due to their being aerial insectivores and colonial nesters (Brown 1988) on rock faces, embankments, and manmade structures, landing within a study site was never observed. During the initial marking of points in 2021, I encountered a Common Nighthawk nest with one egg. The individuals had nested in the chalk flat ecological site with the egg on the bare ground. Each time I would approach the point, I would flush the nesting female and she would fly above me for the duration of the survey swooping down and alerting her mate of my presence. I moved the point 50 m straight west to avoid disturbing the success of the nesting attempt. Upon my return in 2022, I flushed a Common Nighthawk from the same area although I could find no sign of an egg.

Lesser Prairie-Chicken (LPC) are of great importance to Smoky Valley Ranch and the conservation of this species is a top priority. Observing that LPC use similar habitat to other grassland nesting birds was an initial objective for this project before field methods and data were collected. While LPC were spotted during avian surveys, there was never enough data to specifically focus on this species. That said, to support Smoky Valley Ranch's goals, future studies aimed at quantifying a relationship between LPC nesting habitat and VOR should focus on nest searches and measure VOR at areas with confirmed LPC nests. In order to establish a relationship with other grassland birds, avian surveys could be conducted at the known LPC nesting sites and species seen or heard in the same areas could be recorded for comparison of breeding habitat requirements and nesting requirements. With Smoky Valley Ranch falling in the threatened Northern Distinct Population range of the LPC, it would be worth considering efforts focused on ways to assess nesting habitat more easily. in this region with a potential indicator of available nesting habitat such as a grassland bird species found to use the same area for the same purpose.

MANAGEMENT RECOMMENDATIONS

Continued monitoring at Smoky Valley Ranch is necessary to understand the effects of conservation efforts on bird populations at the ranch. Recommendations for continued research are as follows. When conducting VOR measurements, at least three points within an avian point count radius would be advisable to get a more holistic representation of the avian survey area. Since grassland breeding birds are potentially breeding earlier with global climate change, monitoring within the first half of the breeding season each year would potentially capture any shifts in breeding patterns in future years. Making permanent points with small disc markers in the pasture could potentially allow for data to be repeatedly collected to compare habitat usage by species on a yearly basis and monitor usage as VOR changes naturally with management each year. I would suggest utilizing the distance classes I used or subdividing further (0-25 m, 26-50 m, and 51-75 m) to allow for usage of future data in hierarchical distance sampling models. Finally, if a more defined window of VOR for the species of interest is desired, more data points will be necessary to acquire enough species-specific data for analyses. More data points targeting the known habitat of the species of interest on and off the ranch could allow for enough data to establish a defined window of selection for VOR and help increase the effectiveness of additional surveys. If additional species are to be targeted such as the Dickcissel and the Cassin’s Sparrow, taller more dense vegetation in older CRP fields will need to be surveyed as well, because they appeared to prefer those areas.

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TABLES

Table 1.1 Descriptions of covariates and descriptive statistics of covariates used to model an index of abundance (λ) or detection probability (ρ) of grassland birds within six different transects on Smoky Valley Ranch in Logan, Co., KS in summer 2022.

	λ or ρ	SD	Mean	Min	Max	Var
1. VOR	λ and ρ	3.199	5.002	0.350	15.85	10.24
2. P_Dogs	λ	0.305	0.103	0	1.000	0.093
3. Wind	ρ	0.981	2.194	1.000	4.000	0.962
4. Timesince	ρ	65.18	96.90	-7.0	226.0	4248.0
5. Graze	ρ	93.21	52.06	0	333.0	8689.0
6. HOLA	NA	1.227	0.974	0	6	1.506
7. GRSP	NA	0.686	0.427	0	3	0.471
8. WEME	NA	0.654	0.280	0	4	0.428
9. MODO	NA	0.488	0.147	0	3	0.238

VOR is the mean of visual obstruction measurements for each point for each visit. P_Dogs is a nominal variable for absence or presence respectively of prairie dogs. Wind is an ordinal variable of wind in (8.2 kph) classes. Timesince is time in minutes since sunrise. Graze is the number of days since livestock grazing occurred in the same pasture as the point. HOLA is Horned Lark abundance. GRSP is Grasshopper Sparrow abundance. WEME is Western Meadowlark abundance. MODO is Mourning Dove abundance.

Table 1.2 Covariate and bird correlations based on calculations in Program R using correlation function.

	1	2	3	4	5	6	7	8	9
1. VOR	1								
2. P_Dogs	NA	1							
3. Wind	-0.238	NA	1						
4. Timesince	-0.023	NA	0.247	1					
5. Graze	-0.031	NA	0.147	-0.006	1				
6. HOLA	-0.290	NA	0.094	0.015	-0.076	1			
7. GRSP	0.342	NA	-0.246	-0.099	0.030	-0.146	1		
8. WEME	0.171	NA	-0.085	-0.045	0.101	-0.137	0.079	1	
9. MODO	0.249	NA	-0.159	-0.001	-0.129	-0.095	0.109	-0.021	1

VOR is the mean of visual obstruction measurements for each point for each visit. P_Dogs is a nominal variable for absence or presence respectively of prairie dogs. Wind is an ordinal variable of wind in (8.2 kph) classes. Timesince is time in minutes since sunrise. Graze is the number of days since livestock grazing occurred in the same pasture as the point. HOLA is Horned Lark abundance. GRSP is Grasshopper Sparrow abundance. WEME is Western Meadowlark abundance. MODO is Mourning Dove abundance.

Table 2. Horned Lark (*Eremophila alpestris*) mixture and key function for modeling of detection function.

HOLA	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
fit.halfNB	4	728.59	0	0.46	0.46	-359.92
fit.expNB	4	728.59	0	0.46	0.92	-359.92
fit.uniNB	3	732.41	3.81	0.07	0.99	-362.98
fit.hazNB	5	737.12	8.52	0.01	1	-362.98
fit.expP	3	745.59	17	0	1	-369.57
fit.halfP	3	745.59	17	0	1	-369.57
fit.uniP	2	749.49	20.89	0	1	-372.63
fit.hazP	4	753.99	25.4	0	1	-372.62

Horned Lark data was model averaged to assess best mixture and key function for models. NB is a negative binomial distribution. P is a Poisson distribution. Half is short for a half-normal key function, exp is short for an exponential key function, uni is short for a uniform key function, and haz is short for a hazard scale key function. K is the number of parameters in a model. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models; LL is the smallest data value that can belong to the class.

Table 3. Grasshopper Sparrow (*Ammodramus savannarum*) mixture and key function for modeling of detection function.

GRSP	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
fit.uniP	2	491.99	0	0.35	0.35	-243.89
fit.uniNB	3	492.86	0.87	0.23	0.58	-243.21
fit.expP	3	494.22	2.23	0.12	0.69	-243.89
fit.halfP	3	494.22	2.23	0.12	0.81	-243.89
fit.halfNB	4	495.17	3.18	0.07	0.88	-243.21
fit.expNB	4	495.17	3.18	0.07	0.95	-243.21
fit.hazP	4	496.54	4.55	0.04	0.99	-243.89
fit.hazNB	5	498.93	6.93	0.01	1	-243.89

Grasshopper Sparrow data was model averaged to assess best mixture and key function for models. NB is a negative binomial distribution. P is a Poisson distribution. Half is short for a half-normal key function, exp is short for an exponential key function, uni is short for a uniform key function, and haz is short for a hazard scale key function. K is the number of parameters in a model. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models; LL is the smallest data value that can belong to the class.

Table 4. Western Meadowlark (*Sturnella neglecta*) mixture and key function for modeling of detection function.

WEME	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
fit.uniNB	3	378.15	0	0.56	0.56	-185.85
fit.halfNB	4	380.46	2.31	0.18	0.74	-185.85
fit.expNB	4	380.46	2.31	0.18	0.92	-185.85
fit.hazNB	5	382.86	4.71	0.05	0.97	-185.85
fit.uniP	2	385.24	7.09	0.02	0.99	-190.51
fit.expP	3	387.47	9.32	0.01	0.99	-190.51
fit.halfP	3	387.47	9.32	0.01	1	-190.51
fit.hazP	4	389.78	11.63	0	1	-190.51

Western Meadowlark data was model averaged to assess best mixture and key function for models. NB is a negative binomial distribution. P is a Poisson distribution. Half is short for a half-normal key function, exp is short for an exponential key function, uni is short for a uniform key function, and haz is short for a hazard scale key function. K is the number of parameters in a model. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models; LL is the smallest data value that can belong to the class.

Table 5. Mourning Dove (*Zenaida macroura*) mixture and key function for modeling of detection function.

MODO	K	AICc	Delta_AICc	AICcWt	Cum.Wt	LL
fit.uniNB	3	241.71	0	0.52	0.52	-117.63
fit.expNB	4	243.6	1.89	0.2	0.72	-117.42
fit.halfNB	4	243.6	1.89	0.2	0.92	-117.42
fit.hazNB	5	246	4.29	0.06	0.98	-117.42
fit.uniP	2	249.63	7.92	0.01	0.99	-122.71
fit.halfP	3	251.44	9.72	0	0.99	-122.5
fit.expP	3	251.44	9.72	0	1	-122.5
fit.hazP	4	253.75	12.03	0	1	-122.5

Mourning Dove data was model averaged to assess best mixture and key function for models. NB is a negative binomial distribution. P is a Poisson distribution. Half is short for a half-normal key function, exp is short for an exponential key function, uni is short for a uniform key function, and haz is short for a hazard scale key function. K is the number of parameters in a model. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models; LL is the smallest data value that can belong to the class.

Table 6. Total sum counts of birds observed during surveys in 2022 on Smoky Valley Ranch in western Kansas. Abbreviations are alpha codes for bird species.

Common Name	**Scientific Name**	**Alpha Code**	**Sum of Count**
Baltimore Oriole	*Icterus galbula*	BAOR	1
Brown-headed Cowbird	*Molothrus ater*	BHCO	4
Burrowing Owl	*Athene cunicularia*	BUOW	2
Cassin's Sparrow	*Peucaea cassinii*	CASP	2
Cliff Swallow	*Petrochelidon pyrrhonota*	CLSW	29
Common Grackle	*Quiscalus quiscula*	COGR	7
Common Nighthawk	*Chordeiles minor*	CONI	3
Eastern Kingbird	*Tyrannus tyrannus*	EAKI	2
Grasshopper Sparrow	*Ammodramus savannarum*	GRSP	115
Horned Lark	*Eremophila alpestris*	HOLA	367
Kill Deer	*Charadrius vociferus*	KIDE	2
Lark Sparrow	*Chondestes grammacus*	LASP	4
Lesser-Prairie Chicken	*Tympanuchus pallidicinctus*	LEPC	4
Mourning Dove	*Zenaida macroura*	MODO	61
Red-winged Blackbird	*Agelaius phoeniceusi*	RWBL	3
Turkey Vulture	*Cathartes aura*	TUVU	2
Western Kingbird	*Tyrannus verticalis*	WEKI	10
Western Meadowlark	*Sturnella neglecta*	WEME	108
Grand Total			**726**

Table 7. Candidate models for Horned Lark (*Eremophila alpestris*) visit one, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Timesince	716.01	0	0.28	0.28
VOR	Timesince+VOR	717.69	1.67	0.12	0.39

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); and Timesince is the time in minutes since sunrise.

Table 8. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Horned Lark (*Eremophila alpestris)* for visit one on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	-0.13	0.04	-0.18	-0.08
Detection:				
VOR	0.06	0.5	-0.01	0.13
timesince	0.01	0	0	0.01

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables.

Table 9. Candidate models for Horned Lark (*Eremophila alpestris*) visit two, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind	719.93	0	0.19	0.19
VOR	Wind+Graze	720.87	0.94	0.12	0.32

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the models AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); Wind is an ordinal variable classified in 8.05 kph classes; and Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point.

Table 10. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Horned Lark (*Eremophila alpestris)* for visit two on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	-0.13	0.04	-0.18	-0.08
P_Dogs	0.27	0.34	-0.22	0.76
Detection:				
VOR	0.01	0.1	-0.05	0.24
timesince	0.01	0	0	0.01
Wind	0.28	0.15	0.07	0.5
Graze	0	0.1	-0.01	0.0.1

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables.

Table 11. Candidate models for Horned Lark (*Eremophila alpestris*) visit three, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze	722.17	0	0.14	0.14
VOR	Wind+Graze+VOR	722.85	0.69	0.1	0.24
VOR	Wind	723.29	1.12	0.08	0.32
VOR	Wind+VOR	723.53	1.36	0.07	0.39
VOR	Timesince	724.14	1.98	0.05	0.44
VOR	Wind+Graze	722.17	0	0.14	0.14

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 12. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Horned Lark (*Eremophila alpestris)* for visit three on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	-0.1	0.04	-0.15	-0.05
Detection:				
VOR	0.05	0.04	-0.01	0.11
Wind	0.41	0.18	0.14	0.67
graze	-0.01	0.01	-0.02	0

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables.

Table 13. Candidate models for Horned Lark (*Eremophila alpestris*) visit four, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind	724.47	0	0.15	0.15
VOR	Wind+VOR	725.28	0.8	0.1	0.25
VOR	Graze	725.91	1.43	0.07	0.32
VOR	VOR	726.07	1.6	0.07	0.39
VOR	Timesince	726.26	1.78	0.06	0.45
VOR	Wind+Graze	726.47	1.99	0.05	0.5

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the models AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 14. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Horned Lark (*Eremophila alpestris)* for visit four on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	-0.12	0.05	-0.18	-0.05
Detection:				
VOR	0.06	0.07	-0.05	0.16
timesince	0	0	0	0
Wind	0.21	0.17	-0.03	0.45
Graze	0	0.01	-0.01	0.01

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables.

Table 15. Candidate models for Grasshopper Sparrow (*Ammodramus savannarum*) visit one, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR+P_Dogs	Wind+Graze+Timesince+VOR	469.16	0	0.06	0.06
VOR+P_Dogs	Wind+Graze+Timesince	469.16	0	0.06	0.12
VOR+P_Dogs	Wind+Graze+VOR	469.16	0	0.06	0.18
VOR+P_Dogs	Graze+Timesince+VOR	469.16	0	0.06	0.24
VOR+P_Dogs	Wind+Timesince+VOR	469.16	0	0.06	0.3
VOR+P_Dogs	Wind+Timesince	469.16	0	0.06	0.36
VOR+P_Dogs	Wind+VOR	469.16	0	0.06	0.43
VOR+P_Dogs	Wind+Graze	469.16	0	0.06	0.49
VOR+P_Dogs	Graze+VOR	469.16	0	0.06	0.55
VOR+P_Dogs	Graze+Timesince	469.16	0	0.06	0.61
VOR+P_Dogs	Timesince+VOR	469.16	0	0.06	0.67
VOR+P_Dogs	Timesince	469.16	0	0.06	0.73
VOR+P_Dogs	Graze	469.16	0	0.06	0.79
VOR+P_Dogs	VOR	469.16	0	0.06	0.85
VOR+P_Dogs	Wind	469.16	0	0.06	0.91

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 16. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Grasshopper Sparrow (*Ammodramus savannarum)* for visit one on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.13	0.03	0.09	0.17
P_Dogs	-1.67	0.9	-2.96	-0.38
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

Table 17. Candidate models for Grasshopper Sparrow (*Ammodramus savannarum*) visit two, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR+P_Dogs	Wind+Graze+Timesince+VOR	472.44	0	0.06	0.06
VOR+P_Dogs	Wind+Graze+Timesince	472.44	0	0.06	0.12
VOR+P_Dogs	Wind+Graze+VOR	472.44	0	0.06	0.18
VOR+P_Dogs	Graze+Timesince+VOR	472.44	0	0.06	0.24
VOR+P_Dogs	Wind+Timesince+VOR	472.44	0	0.06	0.3
VOR+P_Dogs	Wind+Timesince	472.44	0	0.06	0.36
VOR+P_Dogs	Wind+VOR	472.44	0	0.06	0.42
VOR+P_Dogs	Wind+Graze	472.44	0	0.06	0.48
VOR+P_Dogs	Graze+VOR	472.44	0	0.06	0.54
VOR+P_Dogs	Graze+Timesince	472.44	0	0.06	0.6
VOR+P_Dogs	Timesince+VOR	472.44	0	0.06	0.66
VOR+P_Dogs	Timesince	472.44	0	0.06	0.72
VOR+P_Dogs	Graze	472.44	0	0.06	0.78
VOR+P_Dogs	VOR	472.44	0	0.06	0.84
VOR+P_Dogs	Wind	472.44	0	0.06	0.9

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 18. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Grasshopper Sparrow (*Ammodramus savannarum)* for visit two on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.13	0.03	0.09	0.18
P_Dogs	-1.7	0.94	-3.05	-0.36
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

Table 19. Candidate models for Grasshopper Sparrow (*Ammodramus savannarum*) visit three, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR+P_Dogs	Wind+Graze+Timesince+VOR	469.38	0	0.05	0.05
VOR+P_Dogs	Wind+Graze+Timesince	469.38	0	0.05	0.1
VOR+P_Dogs	Wind+Graze+VOR	469.38	0	0.05	0.15
VOR+P_Dogs	Graze+Timesince+VOR	469.38	0	0.05	0.2
VOR+P_Dogs	Wind+Timesince+VOR	469.38	0	0.05	0.25
VOR+P_Dogs	Wind+Timesince	469.38	0	0.05	0.31
VOR+P_Dogs	Wind+VOR	469.38	0	0.05	0.36
VOR+P_Dogs	Wind+Graze	469.38	0	0.05	0.41
VOR+P_Dogs	Graze+VOR	469.38	0	0.05	0.46
VOR+P_Dogs	Graze+Timesince	469.38	0	0.05	0.51
VOR+P_Dogs	Timesince+VOR	469.38	0	0.05	0.56
VOR+P_Dogs	Timesince	469.38	0	0.05	0.61
VOR+P_Dogs	Graze	469.38	0	0.05	0.66
VOR+P_Dogs	VOR	469.38	0	0.05	0.71
VOR+P_Dogs	Wind	469.38	0	0.05	0.76

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 20. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Grasshopper Sparrow (*Ammodramus savannarum)* for visit three on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.14	0.03	0.1	0.19
P_Dogs	-1.51	0.95	-2.87	-0.15
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

Table 21. Candidate models for Grasshopper Sparrow (*Ammodramus savannarum*) visit four, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR+P_Dogs	Wind+Graze+Timesince+VOR	471.98	0	0.05	0.05
VOR+P_Dogs	Wind+Graze+Timesince	471.98	0	0.05	0.1
VOR+P_Dogs	Wind+Graze+VOR	471.98	0	0.05	0.15
VOR+P_Dogs	Graze+Timesince+VOR	471.98	0	0.05	0.2
VOR+P_Dogs	Wind+Timesince+VOR	471.98	0	0.05	0.25
VOR+P_Dogs	Wind+Timesince	471.98	0	0.05	0.3
VOR+P_Dogs	Wind+VOR	471.98	0	0.05	0.35
VOR+P_Dogs	Wind+Graze	471.98	0	0.05	0.41
VOR+P_Dogs	Graze+VOR	471.98	0	0.05	0.46
VOR+P_Dogs	Graze+Timesince	471.98	0	0.05	0.51
VOR+P_Dogs	Timesince+VOR	471.98	0	0.05	0.56
VOR+P_Dogs	Timesince	471.98	0	0.05	0.61
VOR+P_Dogs	Graze	471.98	0	0.05	0.66
VOR+P_Dogs	VOR	471.98	0	0.05	0.71
VOR+P_Dogs	Wind	471.98	0	0.05	0.76

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 22. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Grasshopper Sparrow (*Ammodramus savannarum)* for visit four on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
Intercept				
VOR	0.17	0.04	0.11	0.22
P_Dogs	-1.54	0.97	-2.94	-0.15
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

Table 23. Candidate models for Western Meadowlark (*Sturnella neglecta*) visit one, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	367.73	0	0.05	0.05
VOR	Wind+Graze+Timesince	367.73	0	0.05	0.09
VOR	Wind+Graze+VOR	367.73	0	0.05	0.14
VOR	Graze+Timesince+VOR	367.73	0	0.05	0.19
VOR	Wind+Timesince+VOR	367.73	0	0.05	0.23
VOR	Wind+Timesince	367.73	0	0.05	0.28
VOR	Wind+VOR	367.73	0	0.05	0.33
VOR	Wind+Graze	367.73	0	0.05	0.37
VOR	Graze+VOR	367.73	0	0.05	0.42
VOR	Graze+Timesince	367.73	0	0.05	0.47
VOR	Timesince+VOR	367.73	0	0.05	0.51
VOR	Timesince	367.73	0	0.05	0.56
VOR	Graze	367.73	0	0.05	0.61
VOR	VOR	367.73	0	0.05	0.65
VOR	Wind	367.73	0	0.05	0.70
VOR+P_Dogs	Wind+Graze+Timesince+VOR	369.43	1.7	0.02	0.72
VOR+P_Dogs	Wind+Graze+Timesince	369.43	1.7	0.02	0.74
VOR+P_Dogs	Wind+Graze+VOR	369.43	1.7	0.02	0.76
VOR+P_Dogs	Graze+Timesince+VOR	369.43	1.7	0.02	0.78
VOR+P_Dogs	Wind+Timesince+VOR	369.43	1.7	0.02	0.80
VOR+P_Dogs	Wind+Timesince	369.43	1.7	0.02	0.82
VOR+P_Dogs	Wind+VOR	369.43	1.7	0.02	0.84
VOR+P_Dogs	Wind+Graze	369.43	1.7	0.02	0.86
VOR+P_Dogs	Graze+VOR	369.43	1.7	0.02	0.88
VOR+P_Dogs	Graze+Timesince	369.43	1.7	0.02	0.90
VOR+P_Dogs	Timesince+VOR	369.43	1.7	0.02	0.92
VOR+P_Dogs	Timesince	369.43	1.7	0.02	0.94
VOR+P_Dogs	Graze	369.43	1.7	0.02	0.96
VOR+P_Dogs	VOR	369.43	1.7	0.02	0.98
VOR+P_Dogs	Wind	369.43	1.7	0.02	1.00

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 24. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Western Meadowlarks (*Sturnella neglecta)* for visit one on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.16	0.05	0.09	0.23
P_Dogs	0.4	0.46	-0.26	1.06
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection variables not modeled due to uniform key function.

Table 25. Candidate models for Western Meadowlark (*Sturnella neglecta*) visit two, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	372.97	0	0.05	0.05
VOR	Wind+Graze+Timesince	372.97	0	0.05	0.09
VOR	Wind+Graze+VOR	372.97	0	0.05	0.14
VOR	Graze+Timesince+VOR	372.97	0	0.05	0.19
VOR	Wind+Timesince+VOR	372.97	0	0.05	0.23
VOR	Wind+Timesince	372.97	0	0.05	0.28
VOR	Wind+VOR	372.97	0	0.05	0.33
VOR	Wind+Graze	372.97	0	0.05	0.37
VOR	Graze+VOR	372.97	0	0.05	0.42
VOR	Graze+Timesince	372.97	0	0.05	0.47
VOR	Timesince+VOR	372.97	0	0.05	0.51
VOR	Timesince	372.97	0	0.05	0.56
VOR	Graze	372.97	0	0.05	0.61
VOR	VOR	372.97	0	0.05	0.65
VOR	Wind	372.97	0	0.05	0.70
VOR+P_Dogs	Wind+Graze+Timesince+VOR	374.79	1.83	0.02	0.72
VOR+P_Dogs	Wind+Graze+Timesince	374.79	1.83	0.02	0.74
VOR+P_Dogs	Wind+Graze+VOR	374.79	1.83	0.02	0.75
VOR+P_Dogs	Graze+Timesince+VOR	374.79	1.83	0.02	0.77
VOR+P_Dogs	Wind+Timesince+VOR	374.79	1.83	0.02	0.79
VOR+P_Dogs	Wind+Timesince	374.79	1.83	0.02	0.81
VOR+P_Dogs	Wind+VOR	374.79	1.83	0.02	0.83
VOR+P_Dogs	Wind+Graze	374.79	1.83	0.02	0.85
VOR+P_Dogs	Graze+VOR	374.79	1.83	0.02	0.87
VOR+P_Dogs	Graze+Timesince	374.79	1.83	0.02	0.89
VOR+P_Dogs	Timesince+VOR	374.79	1.83	0.02	0.90
VOR+P_Dogs	Timesince	374.79	1.83	0.02	0.92
VOR+P_Dogs	Graze	374.79	1.83	0.02	0.94
VOR+P_Dogs	VOR	374.79	1.83	0.02	0.96
VOR+P_Dogs	Wind	374.79	1.83	0.02	0.98

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 26. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Western Meadowlarks (*Sturnella neglecta)* for visit two on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.15	0.05	0.07	0.22
P_Dogs	0.37	0.48	-0.32	1.06
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection variables not modeled due to uniform key function.

Table 27. Candidate models for Western Meadowlark (*Sturnella neglecta*) visit three, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	375.81	0	0.04	0.04
VOR	Wind+Graze+Timesince	375.81	0	0.04	0.08
VOR	Wind+Graze+VOR	375.81	0	0.04	0.12
VOR	Graze+Timesince+VOR	375.81	0	0.04	0.15
VOR	Wind+Timesince+VOR	375.81	0	0.04	0.19
VOR	Wind+Timesince	375.81	0	0.04	0.23
VOR	Wind+VOR	375.81	0	0.04	0.27
VOR	Wind+Graze	375.81	0	0.04	0.31
VOR	Graze+VOR	375.81	0	0.04	0.35
VOR	Graze+Timesince	375.81	0	0.04	0.39
VOR	Timesince+VOR	375.81	0	0.04	0.43
VOR	Timesince	375.81	0	0.04	0.46
VOR	Graze	375.81	0	0.04	0.50
VOR	VOR	375.81	0	0.04	0.54
VOR	Wind	375.81	0	0.04	0.58
VOR+P_Dogs	Wind+Graze+Timesince+VOR	376.84	1.03	0.02	0.60
VOR+P_Dogs	Wind+Graze+Timesince	376.84	1.03	0.02	0.63
VOR+P_Dogs	Wind+Graze+VOR	376.84	1.03	0.02	0.65
VOR+P_Dogs	Graze+Timesince+VOR	376.84	1.03	0.02	0.67
VOR+P_Dogs	Wind+Timesince+VOR	376.84	1.03	0.02	0.70
VOR+P_Dogs	Wind+Timesince	376.84	1.03	0.02	0.72
VOR+P_Dogs	Wind+VOR	376.84	1.03	0.02	0.74
VOR+P_Dogs	Wind+Graze	376.84	1.03	0.02	0.77
VOR+P_Dogs	Graze+VOR	376.84	1.03	0.02	0.79
VOR+P_Dogs	Graze+Timesince	376.84	1.03	0.02	0.81
VOR+P_Dogs	Timesince+VOR	376.84	1.03	0.02	0.84
VOR+P_Dogs	Timesince	376.84	1.03	0.02	0.86
VOR+P_Dogs	Graze	376.84	1.03	0.02	0.88
VOR+P_Dogs	VOR	376.84	1.03	0.02	0.91
VOR+P_Dogs	Wind	376.84	1.03	0.02	0.93

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 28. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Western Meadowlarks (*Sturnella neglecta)* for visit three on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.12	0.06	0.04	0.2
P_Dogs	0.59	0.49	-0.12	1.29
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection variables not modeled due to uniform key function.

Table 29. Candidate models for Western Meadowlark (*Sturnella neglecta*) visit four, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	376.22	0	0.04	0.04
VOR	Wind+Graze+Timesince	376.22	0	0.04	0.07
VOR	Wind+Graze+VOR	376.22	0	0.04	0.11
VOR	Graze+Timesince+VOR	376.22	0	0.04	0.15
VOR	Wind+Timesince+VOR	376.22	0	0.04	0.18
VOR	Wind+Timesince	376.22	0	0.04	0.22
VOR	Wind+VOR	376.22	0	0.04	0.26
VOR	Wind+Graze	376.22	0	0.04	0.29
VOR	Graze+VOR	376.22	0	0.04	0.33
VOR	Graze+Timesince	376.22	0	0.04	0.37
VOR	Timesince+VOR	376.22	0	0.04	0.40
VOR	Timesince	376.22	0	0.04	0.44
VOR	Graze	376.22	0	0.04	0.48
VOR	VOR	376.22	0	0.04	0.51
VOR	Wind	376.22	0	0.04	0.55
VOR+P_Dogs	Wind+Graze+Timesince+VOR	377.02	0.8	0.02	0.57
VOR+P_Dogs	Wind+Graze+Timesince	377.02	0.8	0.02	0.60
VOR+P_Dogs	Wind+Graze+VOR	377.02	0.8	0.02	0.62
VOR+P_Dogs	Graze+Timesince+VOR	377.02	0.8	0.02	0.65
VOR+P_Dogs	Wind+Timesince+VOR	377.02	0.8	0.02	0.67
VOR+P_Dogs	Wind+Timesince	377.02	0.8	0.02	0.70
VOR+P_Dogs	Wind+VOR	377.02	0.8	0.02	0.72
VOR+P_Dogs	Wind+Graze	377.02	0.8	0.02	0.74
VOR+P_Dogs	Graze+VOR	377.02	0.8	0.02	0.77
VOR+P_Dogs	Graze+Timesince	377.02	0.8	0.02	0.79
VOR+P_Dogs	Timesince+VOR	377.02	0.8	0.02	0.82
VOR+P_Dogs	Timesince	377.02	0.8	0.02	0.84
VOR+P_Dogs	Graze	377.02	0.8	0.02	0.87
VOR+P_Dogs	VOR	377.02	0.8	0.02	0.89
VOR+P_Dogs	Wind	377.02	0.8	0.02	0.92

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 30. Model-averaged coefficient estimates for the models examining factors influencing index of abundance and detection probability of Western Meadowlarks (*Sturnella neglecta)* for visit four on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.14	0.06	0.05	0.23
P_Dogs	0.64	0.5	-0.07	1.36
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection variables not modeled due to uniform key function.

Table 31. Candidate models for Mourning Dove (*Zenaida macroura*) visit one, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	234.41	0	0.05	0.05
VOR	Wind+Graze+Timesince	234.41	0	0.05	0.09
VOR	Wind+Graze+VOR	234.41	0	0.05	0.14
VOR	Graze+Timesince+VOR	234.41	0	0.05	0.18
VOR	Wind+Timesince+VOR	234.41	0	0.05	0.23
VOR	Wind+Timesince	234.41	0	0.05	0.27
VOR	Wind+VOR	234.41	0	0.05	0.32
VOR	Wind+Graze	234.41	0	0.05	0.36
VOR	Graze+VOR	234.41	0	0.05	0.41
VOR	Graze+Timesince	234.41	0	0.05	0.45
VOR	Timesince+VOR	234.41	0	0.05	0.50
VOR	Timesince	234.41	0	0.05	0.55
VOR	Graze	234.41	0	0.05	0.59
VOR	VOR	234.41	0	0.05	0.64
VOR	Wind	234.41	0	0.05	0.68
VOR+P_Dogs	Wind+Graze+Timesince+VOR	236.01	1.61	0.02	0.70
VOR+P_Dogs	Wind+Graze+Timesince	236.01	1.61	0.02	0.72
VOR+P_Dogs	Wind+Graze+VOR	236.01	1.61	0.02	0.74
VOR+P_Dogs	Graze+Timesince+VOR	236.01	1.61	0.02	0.76
VOR+P_Dogs	Wind+Timesince+VOR	236.01	1.61	0.02	0.78
VOR+P_Dogs	Wind+Timesince	236.01	1.61	0.02	0.80
VOR+P_Dogs	Wind+VOR	236.01	1.61	0.02	0.83
VOR+P_Dogs	Wind+Graze	236.01	1.61	0.02	0.85
VOR+P_Dogs	Graze+VOR	236.01	1.61	0.02	0.87
VOR+P_Dogs	Graze+Timesince	236.01	1.61	0.02	0.89
VOR+P_Dogs	Timesince+VOR	236.01	1.61	0.02	0.91
VOR+P_Dogs	Timesince	236.01	1.61	0.02	0.93
VOR+P_Dogs	Graze	236.01	1.61	0.02	0.95
VOR+P_Dogs	VOR	236.01	1.61	0.02	0.97
VOR+P_Dogs	Wind	236.01	1.61	0.02	0.99

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 32. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Mourning Doves (*Zenaida macroura)* for visit one on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.19	0.06	0.1	0.28
P_Dogs	-0.92	1.12	-2.53	0.69
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

Table 33. Candidate models for Mourning Dove (*Zenaida macroura*) visit two, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	234.25	0	0.05	0.05
VOR	Wind+Graze+Timesince	234.25	0	0.05	0.09
VOR	Wind+Graze+VOR	234.25	0	0.05	0.14
VOR	Graze+Timesince+VOR	234.25	0	0.05	0.19
VOR	Wind+Timesince+VOR	234.25	0	0.05	0.23
VOR	Wind+Timesince	234.25	0	0.05	0.28
VOR	Wind+VOR	234.25	0	0.05	0.33
VOR	Wind+Graze	234.25	0	0.05	0.37
VOR	Graze+VOR	234.25	0	0.05	0.42
VOR	Graze+Timesince	234.25	0	0.05	0.47
VOR	Timesince+VOR	234.25	0	0.05	0.51
VOR	Timesince	234.25	0	0.05	0.56
VOR	Graze	234.25	0	0.05	0.61
VOR	VOR	234.25	0	0.05	0.65
VOR	Wind	234.25	0	0.05	0.70
VOR+P_Dogs	Wind+Graze+Timesince+VOR	236.01	1.75	0.02	0.72
VOR+P_Dogs	Wind+Graze+Timesince	236.01	1.75	0.02	0.74
VOR+P_Dogs	Wind+Graze+VOR	236.01	1.75	0.02	0.76
VOR+P_Dogs	Graze+Timesince+VOR	236.01	1.75	0.02	0.78
VOR+P_Dogs	Wind+Timesince+VOR	236.01	1.75	0.02	0.80
VOR+P_Dogs	Wind+Timesince	236.01	1.75	0.02	0.81
VOR+P_Dogs	Wind+VOR	236.01	1.75	0.02	0.83
VOR+P_Dogs	Wind+Graze	236.01	1.75	0.02	0.85
VOR+P_Dogs	Graze+VOR	236.01	1.75	0.02	0.87
VOR+P_Dogs	Graze+Timesince	236.01	1.75	0.02	0.89
VOR+P_Dogs	Timesince+VOR	236.01	1.75	0.02	0.91
VOR+P_Dogs	Timesince	236.01	1.75	0.02	0.93
VOR+P_Dogs	Graze	236.01	1.75	0.02	0.95
VOR+P_Dogs	VOR	236.01	1.75	0.02	0.97
VOR+P_Dogs	Wind	236.01	1.75	0.02	0.99

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 34. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Mourning Doves (*Zenaida macroura)* for visit two on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.22	0.07	0.11	0.32
P_Dogs	-0.85	1.13	-2.47	0.78
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

Table 35. Candidate models for Mourning Dove (*Zenaida macroura*) visit three, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	234.21	0	0.05	0.05
VOR	Wind+Graze+Timesince	234.21	0	0.05	0.10
VOR	Wind+Graze+VOR	234.21	0	0.05	0.15
VOR	Graze+Timesince+VOR	234.21	0	0.05	0.19
VOR	Wind+Timesince+VOR	234.21	0	0.05	0.24
VOR	Wind+Timesince	234.21	0	0.05	0.29
VOR	Wind+VOR	234.21	0	0.05	0.34
VOR	Wind+Graze	234.21	0	0.05	0.39
VOR	Graze+VOR	234.21	0	0.05	0.44
VOR	Graze+Timesince	234.21	0	0.05	0.48
VOR	Timesince+VOR	234.21	0	0.05	0.53
VOR	Timesince	234.21	0	0.05	0.58
VOR	Graze	234.21	0	0.05	0.63
VOR	VOR	234.21	0	0.05	0.68
VOR	Wind	234.21	0	0.05	0.73

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 36. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Mourning Doves (*Zenaida macroura)* for visit three on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.21	0.07	0.12	0.31
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

Table 37. Candidate models for Mourning Dove (*Zenaida macroura*) visit four, an estimated index of abundance used for model averaging.

λ	ρ	AICc	ΔAICc	w_i	cumltvw_i
VOR	Wind+Graze+Timesince+VOR	233.73	0	0.05	0.05
VOR	Wind+Graze+Timesince	233.73	0	0.05	0.10
VOR	Wind+Graze+VOR	233.73	0	0.05	0.15
VOR	Graze+Timesince+VOR	233.73	0	0.05	0.20
VOR	Wind+Timesince+VOR	233.73	0	0.05	0.25
VOR	Wind+Timesince	233.73	0	0.05	0.30
VOR	Wind+VOR	233.73	0	0.05	0.35
VOR	Wind+Graze	233.73	0	0.05	0.40
VOR	Graze+VOR	233.73	0	0.05	0.45
VOR	Graze+Timesince	233.73	0	0.05	0.50
VOR	Timesince+VOR	233.73	0	0.05	0.55
VOR	Timesince	233.73	0	0.05	0.60
VOR	Graze	233.73	0	0.05	0.65
VOR	VOR	233.73	0	0.05	0.70
VOR	Wind	233.73	0	0.05	0.74

Data is from 232 surveys in six different transects on Smoky Valley Ranch, in western, Kansas, summer 2022. λ is initial abundance and ρ is detection probability. AICc is Akaike's Information Criterion value adjusted for small sample sizes; ΔAICc is the difference between the top model's AICc and the lowest AICc model; w_i is AICc weight; and cumltvw_i is the cumulative weight of the model plus the higher ranking models. VOR is visual obstruction of vegetation (cm); P_Dogs is a nominal variable indicating absence or presence of prairie dogs within the 75 m radius point count; Wind is an ordinal variable classified in 8.05 kph classes; Graze is the number of days since last livestock prescription grazing occurred in the same pasture as the point; and Timesince is the time in minutes since sunrise.

Table 38. Model-averaged coefficient estimates for models examining factors influencing index of abundance and detection probability of Mourning Doves (*Zenaida macroura)* for visit four on Smoky Valley Ranch, Logan Co., KS. Summer, 2022.

	Estimate	SE	Lower 85% CI	Upper 85% CI
Abundance:				
VOR	0.29	0.1	0.15	0.43
Detection:				

Unconditional standard errors and lower and upper 85% confidence intervals are included for estimates of variables. Detection covariates not modeled due to uniform key function.

FIGURES

Figure 1. Model of VOR to better illustrate methods of vegetation data collection within a point count station at Smoky Valley Ranch during summer 2022.

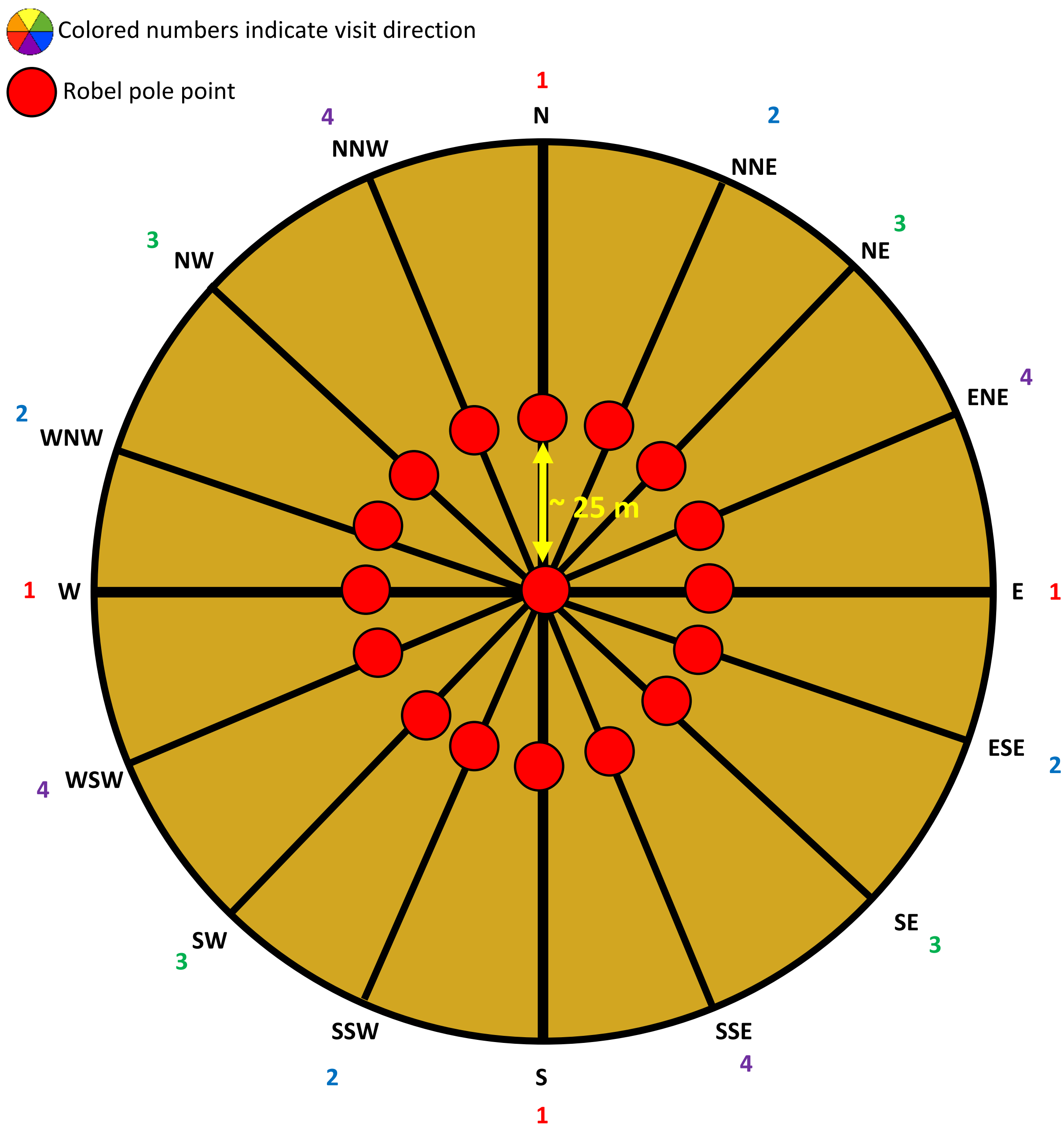

Figure 2. All point count stations from transects one through six.

Figure 3. Point count stations from transects one and two.

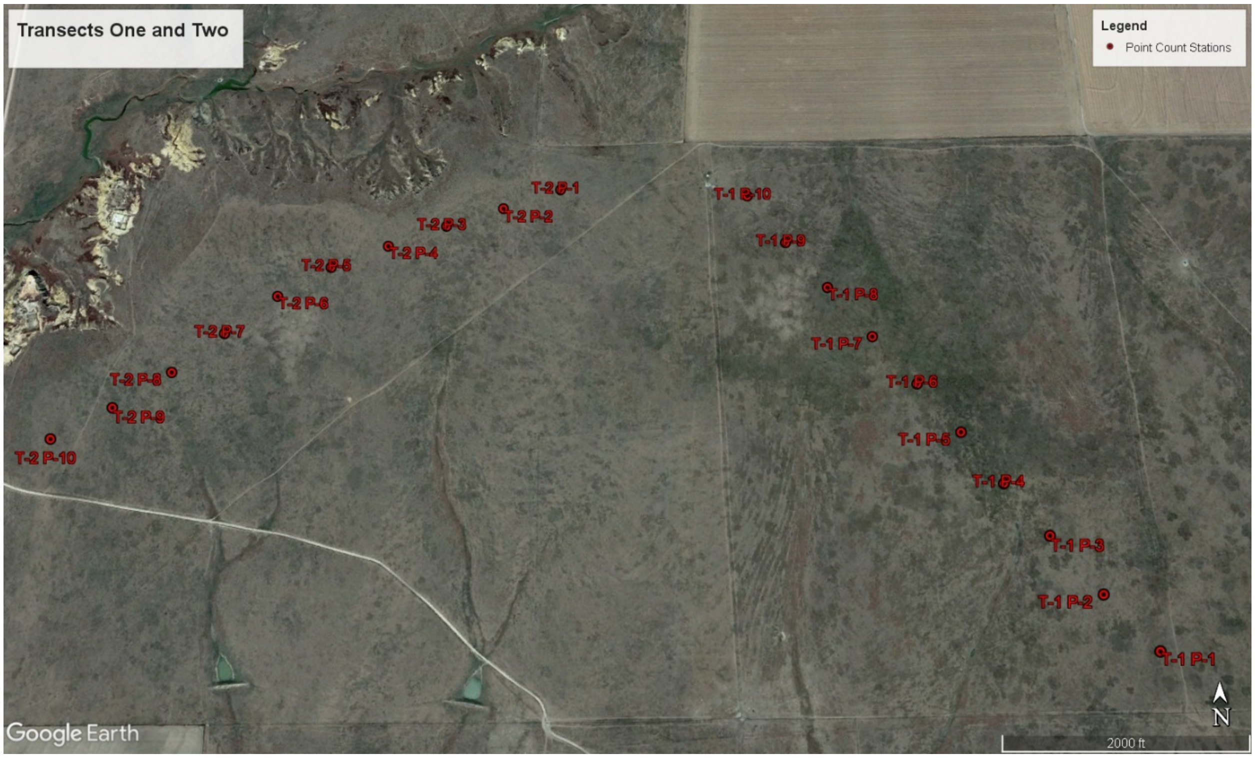

Figure 4. Point count stations from transect three.

Figure 5. Point count stations from transect four.

Figure 6. Point count stations from transect five.

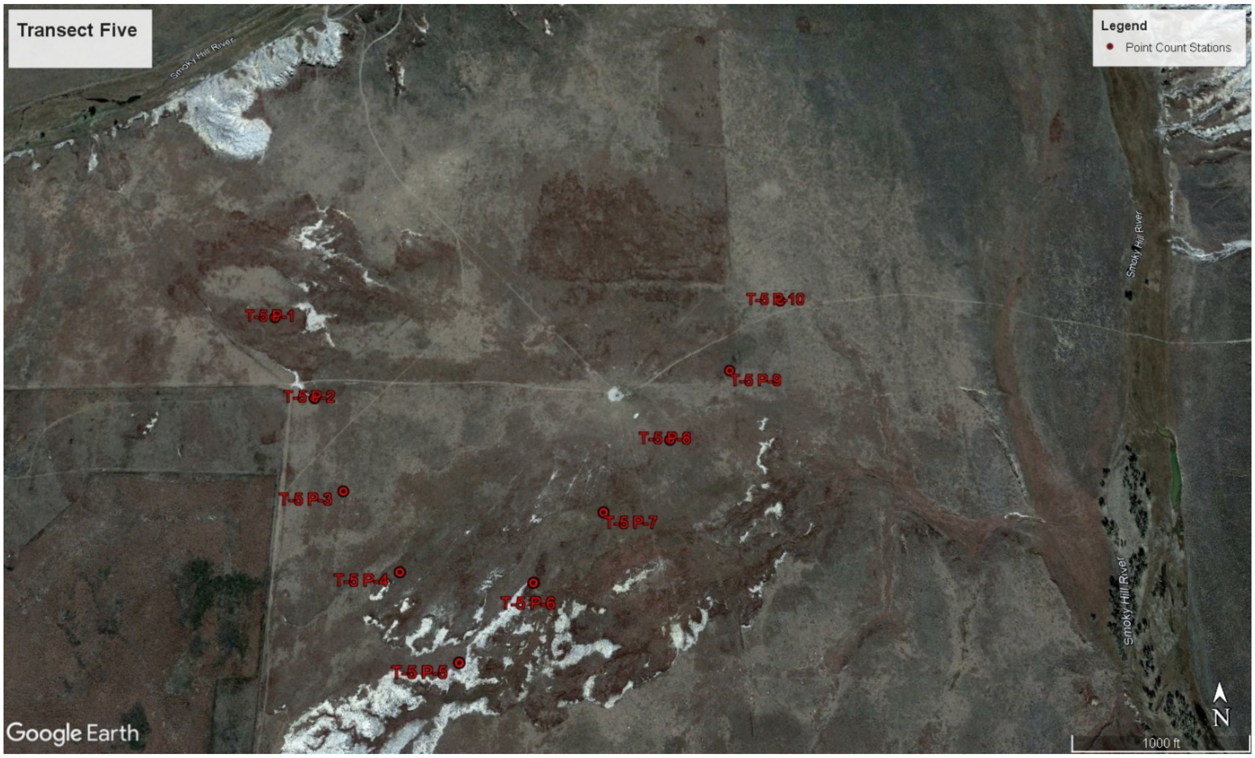

Figure 7. Point count stations from transect six.

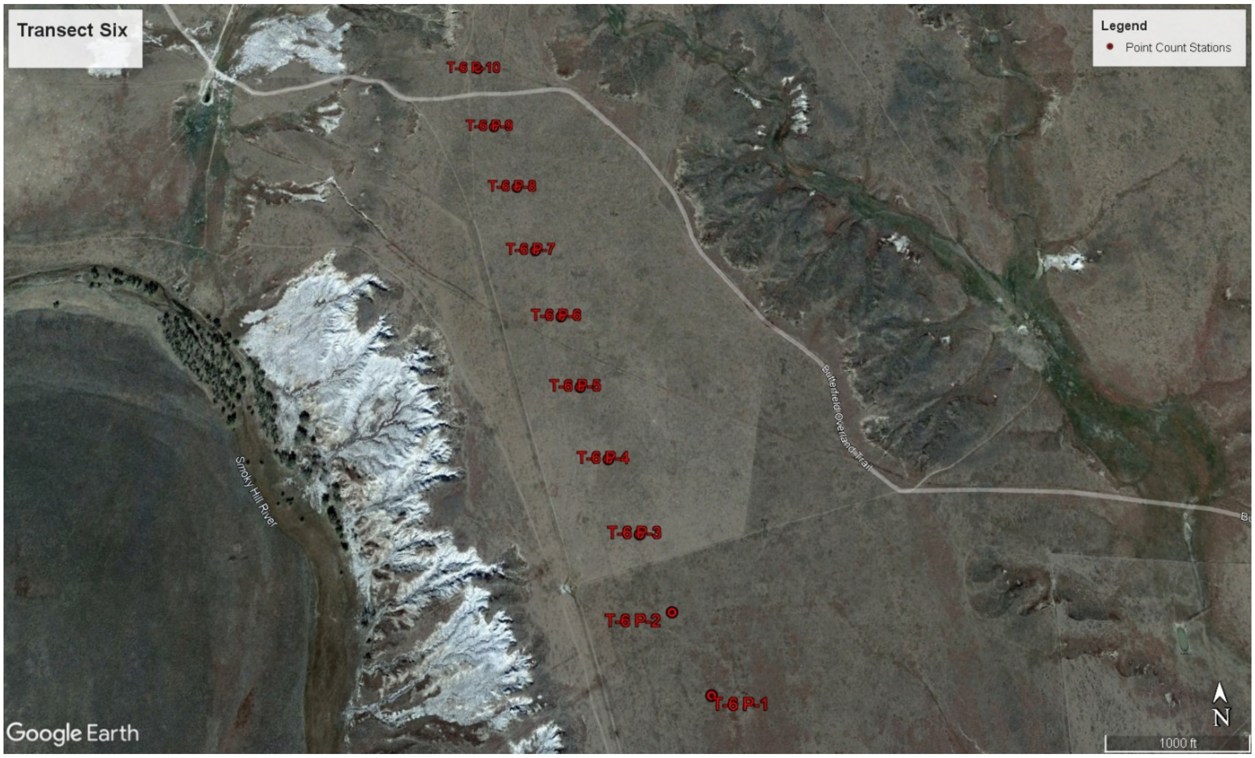

Figure 8. Horned Lark (*Eremophila alpestris*) covariate relationships based on survey visits.

HOLA Trends	Visit One	Visit Two	Visit Three	Visit Four
VOR on Abundance	-	-	-	-
P_Dogs	∅	∅	∅	∅
VOR on Detection	∅	∅	∅	∅
Timesince	+	+	∅	∅
Wind	∅	+	+	∅
Graze	∅	∅	∅	∅

A minus sign (-) indicates there is a negative relationship between bird abundance and the covariate of interest. A plus sign (+) indicates there is a positive relationship between bird abundance and the covariate of interest. A no symbol (∅) indicates there is no relationship between bird abundance and the covariate of interest.

Figure 9. Grasshopper Sparrow (*Ammodramus savannarum*) covariate relationships based on survey visits.

GRSP Trends	Visit One	Visit Two	Visit Three	Visit Four
VOR on Abundance	+	+	+	+
P_Dogs	−	−	−	−

A minus sign (-) indicates there is a negative relationship between bird abundance and the covariate of interest. A plus sign (+) indicates there is a positive relationship between bird abundance and the covariate of interest.

Figure 10. Western Meadowlark (*Sturnella neglecta*) covariate relationships based on survey visits.

WEME Trends	Visit One	Visit Two	Visit Three	Visit Four
VOR on Abundance	+	+	+	+
P_Dogs	∅	∅	∅	∅

A plus sign (+) indicates there is a positive relationship between bird abundance and the covariate of interest. A no symbol (∅) indicates there is no relationship between bird abundance and the covariate of interest.

Figure 11. Mourning Dove (*Zenaida macroura*) covariate relationships based on survey visits.

MODO Trends	Visit One	Visit Two	Visit Three	Visit Four
VOR on Abundance	+	+	+	+
P_Dogs	∅	∅	∅	∅

A plus sign (+) indicates there is a positive relationship between bird abundance and the covariate of interest. A no symbol (∅) indicates there is no relationship between bird abundance and the covariate of interest.

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