

**ECOLOGY, STABLE ISOTOPES, AND MANAGEMENT OF  
GRASSLAND SONGBIRDS AT NATIONAL PARK SERVICE PROPERTIES ON  
THE GREAT PLAINS**

by

Sarah E. Rehme

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Sarah Elizabeth Rehme, M.S.

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Advisers: Larkin A. Powell and Craig R. Allen

Grassland ecosystems have been severely reduced and grassland bird populations have experienced consistent declines. National Park Service (NPS) properties on the Great Plains provide breeding habitat for grassland songbirds, though little is known about the quality of this habitat. A short-term study on songbirds at three NPS properties complemented current monitoring, providing an among park comparison addressing grassland bird productivity and fidelity relative to NPS property size. During 2008-2009, I assessed avian species richness, and estimated bird density and grassland songbird nest success. Bird species richness was greatest at small and medium sites, while number of nesting obligate species was greatest at the large site. Species-specific densities varied among sites, with few grassland obligates occurring at all three sites. Nest success estimates for grassland obligates were highest at the small site and lower at the large site. Another method to quantify habitat quality is assessment of breeding site fidelity. Current extrinsic markers used in monitoring site fidelity are inadequate for small birds; stable isotope analyses provide an alternative. I compared two techniques for assigning stable isotope tissue origin and measured grassland songbird site fidelity. My method of assigning origin provided site-specific variances of expected stable isotope values, an improvement over the most commonly used method. Fidelity tended to be higher at the

large site, which may indicate a more robust breeding community of grassland birds. The small size of two of my sites precluded large sample sizes and made strong inferences difficult. To quantify how scientists cope with weak inference, I conducted a literature review. Strong inference was rarely observed, and most authors of weak-inference papers provided specific management recommendations. I suggest that adaptive management is an ideal method to resolve uncertainty from weak inference. Managers should consider my results within the context of regional and global management and the extent to which their unit might aid songbird conservation.

**DEDICATION**

To my Lord and Savior for such amazing and fascinating organisms to study and for his many blessings in my life.

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## **Chapter 1 : OVERVIEW**

Grasslands were once the most extensive ecosystem in North America but have been drastically reduced due to habitat loss and modification. Some areas in North America have lost as much as 99.9% of native prairie since European settlement (Samson & Knopf 1994). These declines have resulted in corresponding drastic declines in grassland songbird populations. Grassland songbird declines are the fastest, steadiest, and most widespread of any avian assemblage in North America (Knopf 1994). Forty-eight percent of North American grassland breeding birds have shown significant negative population trends since 1980 (Sauer et al. 2008). As a result, it is imperative that remnant prairies and grasslands be maintained at the highest achievable quality.

National Park Service (NPS) units in the Great Plains provide remnant breeding grassland bird habitat. These properties provide multiple services and NPS managers must balance ecological management needs with cultural and historical needs. As a result, techniques that allow managers to monitor and better understand species of concern, and the quality of their habitat, quickly and efficiently are essential. High quality habitat has characteristics that promote successful breeding and high productivity. Powell (2000) suggested that avian productivity studies be conducted at several Great Plains NPS properties to evaluate the relative value of the grassland habitats on these properties for regional songbird production. Current monitoring plans at these sites focus on bird abundance, but bird abundance is not a powerful indicator of breeding success because high densities of grassland birds have been found in habitats with low productivity (Van Horne 1983; Vickery et al. 1992). Therefore, many ecologists focus on

nest success and nest survival to understand the implications of management actions at a given breeding location (e.g., Vickery & Herkert 2001; Herkert et al. 2003; Berkeley et al. 2007).

Searching for and monitoring nests is time consuming and difficult, and some ecologists have begun to focus on site fidelity as an indicator of habitat quality. Birds that bred successfully one year will return to that site the next year, although this pattern does not occur in all species (Bollinger & Gavin 1989; Haas 1998). Monitoring site fidelity is dependent on the ability to track individual birds from one year to the next. Current techniques that utilize external markers such as bands or radio-telemetry do not work well for tracking small species over long periods of time (Powell & Frasch 2000). Intrinsic markers, such as stable isotope analysis, are a promising alternative. Stable isotopes in animal tissues, such as carbon ( $\delta^{13}\text{C}$ ), nitrogen ( $\delta^{15}\text{N}$ ), sulfur ( $\delta^{34}\text{S}$ ), hydrogen ( $\delta\text{D}$ ), and strontium ( $\delta^{87}\text{Sr}$ ), can be used to determine the location of individuals during a previous time period (reviewed by Hobson 2005). Tissues reflect the signature of isotopes of foods previously eaten, and biogeochemical processes cause these signatures to vary spatially. Different tissues carry records of diet stable isotopic signatures from different temporal scales due to metabolic activities in those tissues. Determining the stable isotopic signature of different tissues from the same individual can provide temporal information about that individual's movements (Hobson 2008) and is a possible alternative to traditional mark-recapture studies.

The focus of my research was to describe and quantify the breeding grassland songbird habitat at three NPS properties on the Great Plains: Pipestone National

Monument, Minnesota (Pipestone), Homestead National Monument, Nebraska (Homestead), and Tallgrass Prairie National Preserve, Kansas (Tallgrass). All three locations are multi-use areas, balancing the needs of historical preservation and education, cultural use, and ecological preservation, education, and recreation. To investigate the current state of grassland breeding bird habitat at these locations for management, I focused my research on four species of declining grassland songbirds: dickcissel (*Spiza americana*), grasshopper sparrow (*Ammodramus savannarum*), and western and eastern meadowlark (*Sturnella neglecta*, *Sturnella magna*). During the summers of 2008 and 2009, a crew of technicians and I conducted variable radius point counts to describe species abundance and diversity, searched for and monitored grassland bird nests to determine estimates of nest success, and collected feather and blood samples from adult and nestling target species for use in stable isotope analyses to determine site fidelity.

One challenge of my study was working within the limitations of the smaller park sizes and the corresponding limitation in sample sizes for nests. To make comparisons among large and small properties, I scaled my research efforts at the largest property, Tallgrass, to the size of the smaller properties, Pipestone and Homestead, by utilizing the same number of survey points at all locations (Horn et al. 2000). This limited the number of nests I could find at Tallgrass because grassland songbirds nest densities have a limit (Zimmerman 1971). Working with small sample sizes decreases the possibility of developing strong inference (Anderson et al. 2001) and increases the chance of finding a spurious result or of failing to find an effect that is weak or complex (Johnson 2002).



Such effects are common in ecology and the difficulty is compounded by the short time frame and small scale at which most ecological field research, including my own, is conducted (Wiens 1989).

Managers, policy makers, and funding agencies rely on ecologists to provide management recommendations based on these short, small scale studies. To provide these management recommendations, ecologists, including myself, utilize alternatives to traditional statistical null hypothesis testing, such as multi-model inference, to elucidate the underlying trends in complex data (Anderson et al. 2000; Johnson & Omland 2004; Stephens et al. 2007). However, results of multi-model inference are often equivocal, and ecologists are left with weak inference from which to provide management recommendations. I conducted a literature review of two peer-reviewed, scientific journals that require their authors to provide management or conservation recommendations to quantify the use of multi-model inference, the pervasiveness of weak inference, the type of management recommendation provided, and the degree to which authors acknowledged the uncertainty in weak inference.

My thesis is presented in five chapters. In the first chapter, I introduce the need for my research and an overview of my thesis. In the second chapter, I present my findings on the current state of grassland bird breeding habitat at three NPS properties on the Great Plains and adaptive management recommendations based upon those findings. The third chapter reports site fidelity results based on stable isotope analysis, and my recommendations for the use of these results in a management context. The fourth chapter is a review of the prevalence of weak inference in multi-model inference and

recommendations for authors, editors, and managers based on my results. Chapter four has been accepted by the Journal of Environmental Management for publication and, as a result, differs slightly in format from the other chapters. The last chapter brings my findings from each of these chapters together in a synthetic summary.

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**Chapter 2 : ENHANCING LONG-TERM AVIAN MONITORING PROGRAMS  
WITH SHORT-TERM, FINE-SCALE DATA AT NATIONAL PARK  
SERVICE PROPERTIES**

*Abstract:*

The management of remnant grasslands for declining grassland birds is increasingly important as threats to their habitat, including land conversion and fragmentation, continue. Management must be tailored to a given location due to variation in grassland bird responses to landscape and habitat structure among sites. National Park Service (NPS) properties on the Great Plains provide breeding habitat for grassland songbirds and are part of a long-term avian density monitoring program. A short-term, intensive study on grassland birds at multiple NPS properties complements this long-term monitoring by providing an among park comparison that addresses issues of property size. In 2008 and 2009, I determined site-specific species richness for all birds and grassland obligate birds at three NPS properties on the Great Plains, and I compared the community of birds to Breeding Bird Survey information near the parks. I used distance sampling techniques to estimate density of birds, and I assessed the effect of vegetation and habitat characteristics on grassland songbird nest success. Bird species richness was greater at the two smaller sites, but the largest site was utilized for nesting by the highest number of obligate species. Densities of grassland birds varied among sites, and few of the same grassland obligate species occurred at all three sites. Nest success estimates for grassland obligates were stable at the smallest site but variable between years at the largest site. The large and medium-sized sites contain enough

grassland to attract a large portion of the expected grassland obligate species. The smallest site is too small to develop a management plan that can benefit all grassland birds of concern. However, grassland bird management at the small and medium sites should not be discounted. Small sites should focus management on one or two species that consistently occur in sufficient numbers. All three sites offer opportunities to incorporate long-term monitoring and short-term studies into adaptive management that will draw on the strengths and weaknesses of each approach.

## INTRODUCTION

Native prairies, the largest vegetative province in North America, have been greatly reduced, only about 1% remains following European settlement (Samson & Knopf 1994). Grassland bird populations have also experienced significant and consistent declines – greater than any other group of North American birds – over the last several decades (Sauer et al. 2008). As a result, maintenance and management of remnant grasslands for grassland birds is becoming increasingly important as threats to their habitat continue (Samson & Knopf 1994). Managers of these grasslands often use demographic and community structure data to guide management decisions, and these data are collected through monitoring and research.

National Park Service (NPS) properties on the Great Plains have remnant patches of prairie. The Heartland Inventory and Monitoring Network (HTLN), part of the NPS Nationwide Inventory and Monitoring program, conducts inventories and monitoring of natural resources to aid management decisions at NPS properties (Peitz et al. 2008). The goal of HTLN is to establish long-term trends across a wide range of natural resources, including grassland songbirds, encompassing a large geographic extent. Such a large scale program necessarily creates logistic constraints and NPS properties are sampled about every 3 years (Peitz et al. 2008). A short-term, intensive study on grassland birds at multiple NPS properties has the potential to complement these long-term data and add to the information available to make management decisions in an adaptive fashion.

Great Plains NPS properties vary in size, vegetation community, climate, and the composition of the surrounding landscape. Some of these properties are relatively small



and grassland songbirds are sensitive to the area of available breeding habitat (Vickery et al. 1994; Helzer & Jelinski 1999; Winter & Faaborg 1999; Winter et al. 2006). There is debate as to the minimum area of contiguous grassland needed for a healthy, diverse community (Vickery et al. 1994; Helzer & Jelinski 1999; Johnson & Igl 2001) and the degree to which these birds respond to grassland area (Herkert 1994; Johnson & Igl 2001). Johnson and Igl (2001) argue that study results from one region may not apply to another because grassland bird responses to area are not consistent and conclusive among sites for any one species. These inconsistencies could be due to interactions among grassland area, bird densities, species range, and vegetation composition (Rotenberry 1985; Johnson & Igl 2001). Thus it is necessary to investigate the adequacy of the size of any property in context of these variables through monitoring and research.

Current monitoring at Great Plains NPS properties provides important information about grassland bird communities. Nevertheless, the data compiled from avian monitoring, such as abundance and density, don't fully portray the current state of avian breeding in the grassland. Low nest survival and success have been observed in areas with high abundance (Van Horne 1983; Vickery et al. 1992; Winter & Faaborg 1999). Recently, ecologists have begun to focus more on nest success and productivity to identify habitat where bird populations are successfully reproducing (e.g., Vickery & Herkert 2001; Herkert et al. 2003; Churchwell et al. 2008). However, productivity data can be especially time consuming and expensive to collect in grassland systems, given the difficulty of locating and relocating nests that generally occur at low densities. The

accumulation of both long-term density information and short-term nesting success data at NPS properties has the potential to guide management decisions.

Although short term studies can have the benefit of allocating resources in a more intensive way, the results of those studies are not sensitive to long-term annual variation, the scale at which management decisions affect ecosystems (Wiens 1989). Therefore, both short-term and long-term studies alone cannot fully address the gaps in information needed to manage a complex ecosystem, such as a grassland. These studies would both benefit from techniques that allow their strengths to be combined for effective management. Adaptive management is a process that allows data gleaned from intensive, short-term studies to be combined with knowledge gained from long-term monitoring. This data can be used to make informed management decisions and to continue adapting those decisions based on the evaluation of management results within the context of management objectives (Holling 1978; Walters 1986). The U.S. Department of the Interior, of which NPS is a component, has mandated that adaptive management be implemented in land and natural resource decisions within the department (Williams et al. 2007).

Better understanding of the current state of NPS properties on the Great Plains through a short-term study will greatly assist NPS managers to make informed and effective management decisions within the context of adaptive management. To depict the present state of grassland breeding bird ecology at three Great Plains NPS properties for the purpose of management, I (1) described the grassland bird community structure at each site and compared the results with species lists compiled from Breeding Bird Survey

data, (2) described vegetation structure and composition at each site, (3) described grassland breeding bird density to compare grassland songbird densities among study sites, and (4) assessed vegetation structure and composition effects on daily nest survival and nest success for grassland songbirds for comparison among study sites. I expected grassland obligate species richness to be highest at the largest site and the largest site to have the most species of nesting grassland birds. I expected densities of grassland obligates that have large territories to be higher at the largest site, but I did not expect this trend to be consistent across all species. I expected target species nest success to be highest at the largest site and to be lower at smaller sites.

## **METHODS**

### **STUDY SITES**

My study was conducted May through August of 2008 and 2009 at three NPS properties: Tallgrass Prairie National Preserve in Kansas (4395 ha), Pipestone National Monument in Minnesota (114 ha), and Homestead National Monument in Nebraska (65 ha). These sites were selected because they represent extremes of NPS property size on the Great Plains, are relatively close together (spanning ~630km), and are all tallgrass prairie. Managers at these properties must balance the historical, cultural, and educational functions with ecological goals, including grassland songbird conservation, set forth by their natural resource management plans. Tallgrass Prairie National Preserve (hereafter Tallgrass) contains 4,395 ha of tallgrass prairie and is surrounded by rangeland. Tallgrass is composed of two sections (west: 3,036 ha; east: 1,359 ha), and I selected sampling sites in the western portion of Tallgrass to meet logistical constraints.

Pipestone National Monument (Pipestone), the medium site, contains 82 ha of tallgrass prairie and is surrounded by private land, row crops, the city of Pipestone, and a state wildlife management area. Homestead National Monument (Homestead) is the smallest site, containing 36 ha of prairie, and is surrounded by row crops and housing. I avoided areas of Pipestone where Native American ceremonies were performed and where a population of threatened western prairie fringed orchid (*Platanthera praeclara*) was located. Tallgrass is grazed by cattle annually and burned rotationally every 2-3 years. Sections of Pipestone and Homestead are burned rotationally once every three years.

## STUDY SPECIES

Lichtenberg and Powell (2000) and Powell (2000) reported that dickcissels (*Spiza americana*), grasshopper sparrows (*Ammodramus savannarum*), and western and eastern meadowlarks (*Sturnella neglecta*, *Sturnella magna*) were among the most abundant birds at my study sites. Each of these species has declined significantly in the study area during 1966-2007 (Sauer et al. 2008). I selected these as target species for daily nest survival analyses.

## SAMPLING METHODS

### *Avian Surveys*

I used points pre-selected in a random manner by the Heartland Monitoring Network for my variable radius avian point count surveys, which allowed use of my data by HTLN and *vice versa*. I limited the surveys to points in prairie habitat: 58 at Pipestone, 34 at Homestead, and 40 at Tallgrass. This design, with a similar number of

study points at each site, enables comparisons among properties and decreases sampling bias (Horn et al. 2000). Points were surveyed seven times each field season: four times within a two-week period in May/June and three times within a two-week period in July/August. Each of two surveyors was assigned half the points to survey in any given iteration and sets of points were alternated between the two surveyors with each iteration. We surveyed points from sun-rise until about 10:30am. Each survey was 5 minutes long with a 1 minute acclimation period at the beginning of the survey. We followed distance sampling protocol (Buckland et al. 2001), and primary emphasis was given to grassland bird species. Every bird seen and heard during the 5 min was recorded, a distance measurement was taken using a range finder, and the type of cue (audio or visual) and the bird's behavior was recorded. We recorded weather, wind speed, temperature, and disturbances (cattle in the vicinity, cars passing, etc.) during the survey. To describe vegetation structure and composition at survey points, vegetation was sampled at each survey point using the same methods as for nest vegetation sampling (see *Nest Vegetation Sampling* below).

#### *Nest Monitoring*

My field assistants and I located grassland bird nests by searching systematically (Davis 2005) and observing adult behavior. Upon initial discovery of a nest, we candled at least 2 eggs to determine nest age (Lokemoen & Koford 1996), and location was recorded using a GPS handheld device. We marked each nest with flags placed 5m to the north and south of the nest. We subsequently monitored each nest every 3-4 days until fledging of young or nest failure (Appendix B). Visits to nests were minimized as much

as possible in duration and frequency, and field assistants approached the nest from different directions during monitoring to lessen cues for nest predators.

### *Nest Vegetation Sampling*

We measured vegetation structure and composition at each nest upon completion of nesting. We measured visual obstruction using a visual obstruction pole (Robel et al. 1970) in the four cardinal directions at three points 10m from each nest in a triangle around the survey point at 0°, 120°, and 240°. These measurements serve as an indicator of vegetation structure (i.e., biomass, and thus density). We estimated percent functional vegetation cover for each descriptive plant group (woody, forb, grass, litter, and bare ground) within a 50-cm x 50-cm quadrat placed over the nest with the sides of the quadrat facing the cardinal directions; our estimates allowed for vegetation overlap and total cover could exceed 100% (Daubenmire 1959). Using a range finder, we recorded the distance to the nearest edge in each cardinal direction, where edge is defined as structure that a grassland bird predator can sit on (powerline, fence post, etc.), a habitat where a predator lives or hunts (trees, bushes, etc.), or a man-made structure (road, hiking trail, etc.).

## STATISTICAL ANALYSIS

### *Species Richness*

To obtain a measure of species richness, I calculated the number of species detected over all surveys at all points within each park across years (Appendix A). I used Poole (2005) to classify each species as a grassland nesting obligate or non-obligate. I

defined grassland nesting obligate species as requiring relatively treeless grassland for successful nesting. I classified species as nesting in the grassland habitat at each site based upon observations of nests found while nest searching or conducting surveys.

To compare species recorded at my study sites with the species from a secondary reference within the same region of each site, I used Breeding Bird Survey (BBS) data to derive a list of expected grassland obligate species. The BBS is a long-term, nation-wide survey conducted by volunteers and coordinated by the U.S. Geological Survey. I utilized these data because they are standardized among survey routes, and routes represent a wider variety of landscape cover classes than my sites. I selected the BBS route nearest each study site where data were available (Pipestone: route #50006, Ash Creek, MN; Homestead: route #38028, Hanover, KS; Tallgrass: route #38017, Ellinor, KS) and limited my species pool to all historical records of breeding birds detected from 2000-2009. Data for Ash Creek, MN, were only available from 2004-2009 (USGS Patuxent Wildlife Research Center 2010).

### *Density*

I used program Distance to estimate bird density (Thomas et al. 2010) using distance estimation techniques (Buckland et al. 2001). I ran four types of models (null, observer, cue, and wind) with two cosine key functions (half-normal and hazard-rate) for observer, cue, and wind models, and four cosine key functions (half-normal, uniform, hazard-rate, and negative exponential) for the null model. The null model contained no covariates to explain variability in detection probability, other than distance from observer. Sauer et al. (1994) found observer skill and experience affected detection, so I

assessed this using a model that estimated detection probabilities for each observer. Detection probabilities may vary by the type of initial cue (aural or visual; Buckland et al. 2001), so I included a cue model, which estimated detection probabilities for each type of cue. Simons et al. (2007) found wind speed to decrease the observer's ability to detect birds, so I included wind speed (Beaufort Scale) as a covariate in the wind model. For each study site, I ran the four types of models for each species with >15 records. I allowed Distance to determine the cut points and effective width. Model fit was assessed using Kolmogorov-Smirnov Goodness-of-fit tests. I used Akaike's Information Criterion, adjusted for small sample sizes ( $AIC_c$ ), to select my confidence set of models based on  $AIC_c$  weights ( $w_i$ ) and Royall (1997), where models with weights below 10% of the weight of the top model were not considered plausible.

#### *Daily Nest Survival*

I used multi-model inference to determine the best model for estimating nest survival. Time-specific variables have been shown to affect passerine nest survival (Grant et al. 2005), so I included nest age in days since the start of incubation (age) and the day in the nesting season (days since May 1; day) as model variables. The age of each nest was determined from candling and/or back calculating from observed nesting events (i.e., hatching, fledging) based on a 24d meadowlark nesting cycle (13d of incubation; Lanyon 1995), a 21d dickcissel cycle (12d of incubation; Temple 2002), and a 20d grasshopper sparrow cycle (12d of incubation; Vickery 1996). I selected combinations of percent cover of 5 functional groups (woody, forb, grass, litter, bare) and height of the nest cup rim above the ground (ht) based on nesting habitat descriptors for



target species derived from the Birds of North America Online (Lanyon 1995; Vickery 1996; Temple 2002; Davis & Lanyon 2008). I calculated the average distance to edge (edge) using measurements taken in the field (see above) and Geographic Information System (GIS) measurements for edges that were >300m from the nest. Patch burn/grazing regimes have been shown to affect grassland bird breeding success (Churchwell et al. 2008). I determined the number of years since last burn for each nest (BY) using GIS files provided by NPS personnel from each study site. I calculated an average visual obstruction reading for the nest (VOR) by averaging the four VOR readings at the three points in a triangle around the nest. I calculated a small-scale heterogeneity index (SSH; Wiens 1974) to quantify the heterogeneity at each nest:

$$SSH = \frac{(VOR_{Max} - VOR_{Min})}{VOR_{\bar{x}}}$$

where,  $VOR_{Max}$  = maximum visual obstruction reading recorded among the three sample points,  $VOR_{Min}$  = minimum visual obstruction reading among the three sample points, and  $VOR_{\bar{x}}$  = the mean visual obstruction reading among the three sample points.

I proposed four sets of *a priori* covariates that I used to construct additive models based on the log exposure method (Shaffer 2004) using Program R (R Development Core Team 2008). I used a logistic regression model for nest survival analysis, which is a generalized linear model with a binomial response distribution, a logistic function systematic component, and a modified logit link function ( $\log_e[p/(1-p)]$ , where  $p$  = probability of a success). The logistic regression assumes survival/failure of each nest is independent of all other nests and that daily survival rates are homogeneous among nest-days having the same explanatory variables (Shaffer 2004). My sets of covariates were

time (age, day), location (height, edge, burn-year), vegetation structure (VOR, SSH), and vegetation composition (woody, forb, grass, litter, bare; Table 4). I conducted separate analyses for each year. For 2009 model selection, I removed any parameters included in 2008 where covariate values were constant across all nests (Table 5 and 6, Appendix B). Due to high model selection uncertainty, I pooled my 2008 and 2009 data and conducted a third analysis (Table 4). I was unable to fit global models due to the small sample sizes for each species. I conducted a separate analysis, using distinct combinations of covariate sets, for each species to represent *a priori* hypotheses. I included a null model (no effects) in each species' set of candidate models. I used Akaike's Information Criterion adjusted for small sample sizes ( $AIC_c$ ) to rank the candidate models and Akaike weights ( $w_i$ ) to determine the weight of evidence supporting each candidate model (Burnham & Anderson 2002).

Due to high model selection uncertainty, I derived a model averaged estimate of daily nest survival based on conditional averaging (Burnham & Anderson 2002). I held all parameters constant at the mean or median for continuous variables and the most common category for categorical variables and derived a daily nest survival estimate from each model by weighting each estimate by  $w_i$  from the corresponding model. I extrapolated a nest success probability estimate by exponentiating each daily nest survival estimate ( $\hat{S}$ ) by the length of each species' nesting cycle (e.g.,  $\hat{S}^{24}$  for eastern meadowlarks). I repeated this process for the 2008, the 2009, and the pooled analyses.

## RESULTS

### *Species Richness*

Species richness for all birds observed during surveys was highest at the most northerly site, Pipestone, and lowest at the large, most southern site, Tallgrass (Table 1). Tallgrass had the lowest species richness but the greatest number of obligate grassland nesting species, including the dickcissel, eastern meadowlark, grasshopper sparrow, Henslow's sparrow (*Ammodramus henslowii*), lark sparrow (*Chondestes grammacus*), and upland sandpiper (*Bartramia longicauda*). We found the greatest number of species nesting within the grasslands at Pipestone, including shrub and woodland species, but found only 2 nesting obligate species (Table 1), including bobolink (*Dolichonyx oryzivorus*) and ring-necked pheasant (*Phasianus colchicus*). Homestead had only dickcissels as obligate nesters.

We observed all expected BBS species at Tallgrass, and we also observed greater prairie-chicken (*Tympanuchus cupido*), Henslow's sparrow, northern harrier (*Circus cyaneus*), and western meadowlark, which were not observed on the BBS route. We observed 8 of the 10 BBS species at Pipestone. In addition, we observed three species, grasshopper sparrow, lark sparrow, and northern harrier, which were not recorded on the BBS route. We did not observe 2 species observed on the BBS route: eastern meadowlark and horned lark (*Eremophila alpestris*). At Homestead, we observed 7 of 9 BBS grassland obligate species (Table 1). Horned lark and upland sandpiper were BBS species that were not observed at Homestead.

Table 1. Measurements of avian community composition based on surveys and nest searching conducted May-August 2008 and 2009 at Tallgrass Prairie National Preserve, Kansas, Pipestone National Monument, Minnesota, and Homestead National Monument, Nebraska, USA.

Location	Species Richness <sup>a</sup>	Nesting Obligates <sup>b</sup>	Nesting Species <sup>c</sup>	Observed Obligates <sup>d</sup>	BBS Obligates <sup>e</sup>
Tallgrass	48	6	9	10	6
Pipestone	67	2	10	11	10
Homestead	57	1	7	7	9

<sup>a</sup> Count of all species observed from prairie survey points

<sup>b</sup> Count of obligate grassland species based upon observed nesting

<sup>c</sup> Count of total species nesting in grassland habitat based upon observed nesting

<sup>d</sup> Count of obligate grassland birds observed from prairie survey points

<sup>e</sup> Count of obligate grassland birds expected at the location based on Breeding Bird Survey data

### *Site Vegetation*

Overall vegetation density tended to be lowest at Tallgrass and highest at Homestead for both years (Fig. 1). Grass tended to have the highest percent functional cover out of all cover classes measured at Tallgrass (Fig. 2a). Percent litter and percent grass were the highest cover classes at Pipestone (Fig. 2b). Litter, grass, and forb tended to have the highest percent cover at Homestead (Fig. 2c). Percent bare ground tended to be higher at Tallgrass and Pipestone than at Homestead, and percent woody cover tended to be higher at Pipestone and Homestead than at Tallgrass (Fig. 2).

### *Density*

Densities of grassland birds varied among parks, with few of the same grassland obligate species occurring at all three sites (Table 2; see Appendix A). I found grassland obligates to be the most dense set of species at Tallgrass, including dickcissel, grasshopper sparrows, Henslow's sparrows, and eastern meadowlarks (Table 2). Bobolink, brown-headed cowbird (*Molothrus ater*), clay-colored sparrow (*Spizella*

*pallida*), and red-winged blackbird (*Agelaius phoeniceus*) were the most common species at Pipestone across years. The most common grassland obligates at Pipestone were bobolink and western meadowlark. Red-winged blackbird, dickcissel, and common-yellowthroat (*Geothlypis trichas*) had the highest density at Homestead both years.

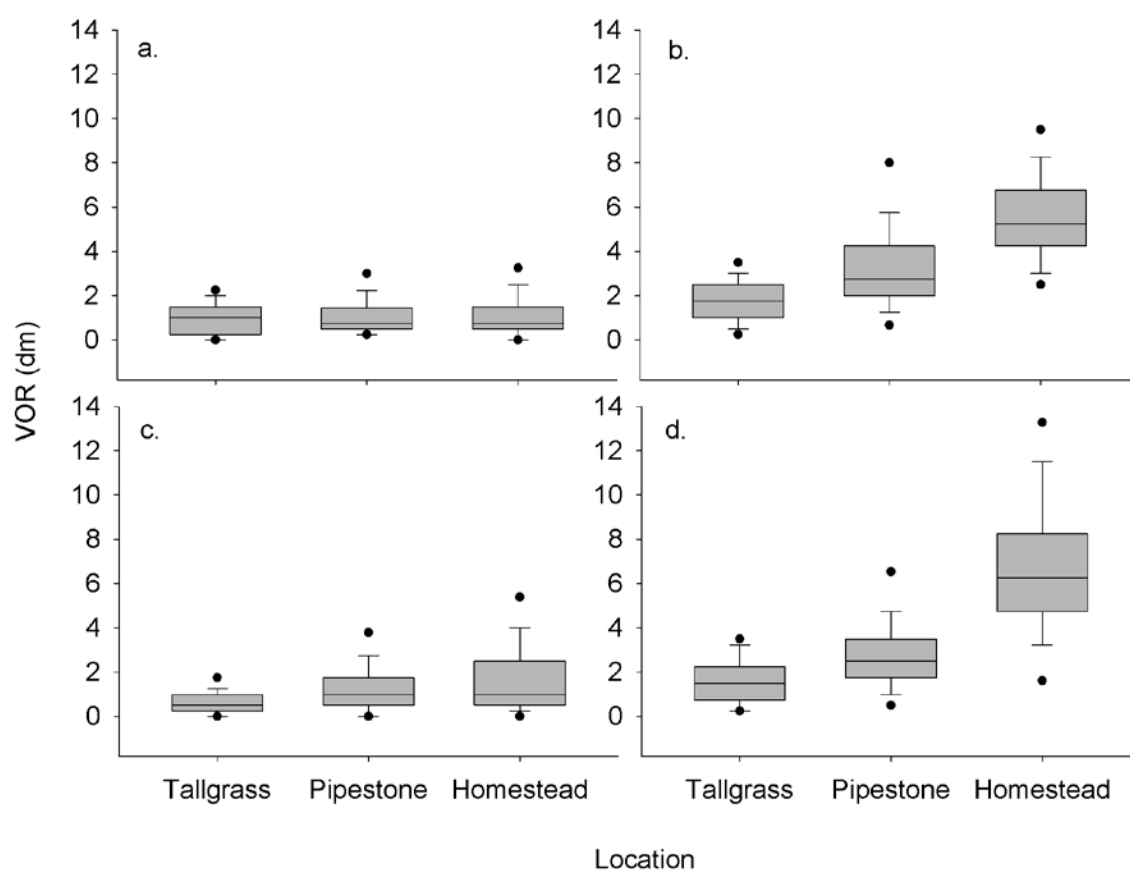


Figure 1. Visual obstruction readings at grassland songbird survey points at Tallgrass Prairie National Preserve, Kansas, Pipestone National Monument, Minnesota, and Homestead National Monument, Nebraska, USA, in May/June of 2008 (a), July/August of 2008 (b), May/June of 2009 (c), and July/August of 2009 (d). Shown are median line (horizontal line in center of each box), 25<sup>th</sup> and 75<sup>th</sup> percentiles (ends of boxes), 10<sup>th</sup> and 90<sup>th</sup> percentiles (vertical lines), and 5<sup>th</sup> and 95<sup>th</sup> percentiles (closed circles).

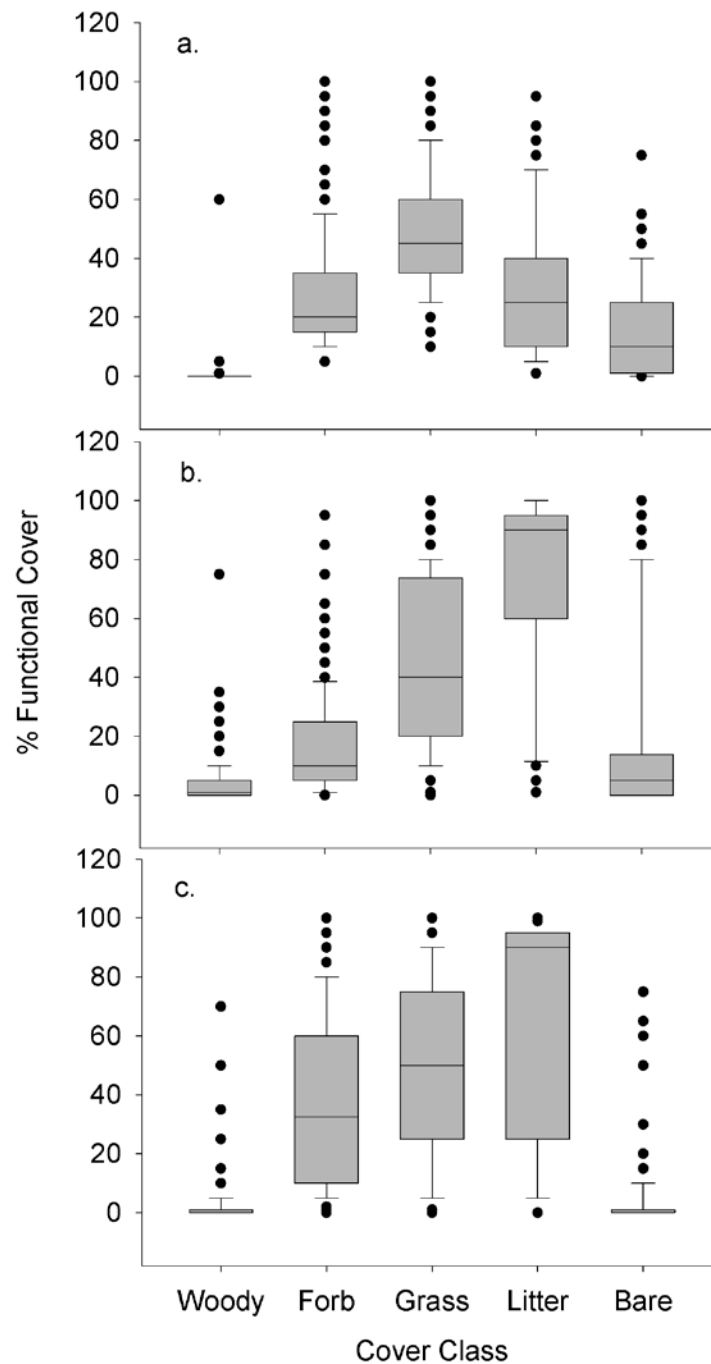


Figure 2. Percent functional ground cover by cover class at grassland songbird survey points at Tallgrass Prairie National Preserve, Kansas (a), Pipestone National Monument, Minnesota (b), and Homestead National Monument, Nebraska (c), 2008-2009. Each year includes two measurements at each point, one in May/June and one in July/August. Shown are median line (horizontal line in center of each box), 25<sup>th</sup> and 75<sup>th</sup> percentiles (ends of boxes), 10<sup>th</sup> and 90<sup>th</sup> percentiles (vertical lines), and outliers (closed circles).

Table 2. Density (95% CI) of grassland bird species (birds/ha) based on point count surveys at Tallgrass Prairie National Preserve, Kansas (Tall), Pipestone National Monument, Minnesota (Pipe), and Homestead National Monument, Nebraska (Home), USA, during the summers of 2008 and 2009. See Appendix A for more extensive density estimate results.

Species	Tall	2008 Pipe	Home	Tall	2009 Pipe	Home
Bobolink*	-	0.083 (0.061-0.113)	- <sup>a</sup>	-	0.303 (0.237-0.387)	-
Brown-headed Cowbird	0.130 (0.107-0.157)	0.021 (0.015-0.030)	0.111 (0.047-0.262)	0.169 (0.132-0.218)	0.148 (0.097-0.226)	0.114 (0.083-0.156)
Clay-colored Sparrow	-	0.042 (0.031-0.055)	-	-	0.085 (0.061-0.120)	-
Common Nighthawk	0.016 (0.010-0.027)	-	-	0.009 (0.006-0.014)	P	-
Common Yellowthroat	P	0.011 (0.007-0.017)	0.233 (0.188-0.291)	-	0.044 (0.034-0.058)	0.170 (0.141-0.205)
Dickcissel*	0.433 (0.391-0.480)	0.003 (0.002-0.004)	0.313 (0.272-0.361)	0.190 (0.169-0.214)	-	0.252 (0.223-0.285)
Eastern Meadowlark*	0.260 (0.228-0.296)	-	0.006 (0.002-0.015)	0.092 (0.080-0.105)	-	-
Grasshopper Sparrow*	0.382 (0.334-0.437)	P <sup>b</sup>	P	0.336 (0.283-0.398)	P	-
Greater prairie-chicken*	P	-	-	P	-	-
Henslow's Sparrow*	-	-	-	0.177 (0.069-0.454)	-	-
Horned Lark*	P	-	-	-	-	-

Table 3. continued.

Species	Tall	2008 Pipe	Home	Tall	2009 Pipe	Home
Lark Sparrow*	P	P	P	-	-	-
Mourning Dove	0.006 (0.001-0.030)	0.003 (0.001-0.006)	0.006 (0.003-0.013)	0.004 (0.003-0.007)	0.008 (0.006-0.012)	0.008 (0.006-0.011)
Northern Bobwhite	0.020 (0.014-0.028)	-	P	0.003 (0.002-0.003)	-	0.004 (0.000-0.255)
Northern Harrier*	-	-	-	-	P	-
Red-winged Blackbird	0.010 (0.007-0.014)	0.041 (0.030-0.056)	0.340 (0.271-0.426)	0.007 (0.006-0.010)	0.022 (0.017-0.029)	0.484 (0.350-0.670)
Ring-necked Pheasant*	-	0.009 (0.007-0.011)	0.041 (0.025-0.067)	-	0.013 (0.010-0.016)	0.004 (0.002-0.010)
Savannah Sparrow*	-	0.015 (0.009-0.026)	-	-	0.004 (0.001-0.016)	-
Sedge Wren*	-	0.009 (0.006-0.012)	P	-	0.041 (0.023-0.072)	-
Upland Sandpiper*	0.018 (0.014-0.024)	-	-	0.005 (0.004-0.007)	P	-
Vesper Sparrow*	-	P	-	-	-	-
Western Meadowlark*	0.002 (0.00-0.024)	0.012 (0.009-0.016)	P	-	0.002 (0.001-0.003)	-

<sup>a</sup> No observation<sup>b</sup> P = species was observed during surveys, but without sufficient numbers to estimate density using distance estimation techniques

\* Denotes grassland obligate species



### *Nest Survival and Success*

We monitored 54 dickcissel nests (30 at Tallgrass, 0 at Pipestone, 21 at Homestead,), 19 eastern meadowlark (all at Tallgrass), and 20 grasshopper sparrow nests (all at Tallgrass) during May through August of 2008 and 2009. Approximately 120 hr of nest searching was conducted at each location per year. Dickcissel, eastern meadowlark, and grasshopper sparrow nests were observed at Tallgrass (Table 3). No target species nests were observed at Pipestone, although we observed Western meadowlarks utilizing the prairie habitat at Pipestone all season long. Dickcissel nests were the most abundant nests observed at Homestead. Eastern meadowlarks and grasshopper sparrows were observed at Homestead briefly at the beginning of the field season, but no nesting behavior was observed.

Table 3. Daily nest survival and nest success estimates (95% confidence intervals) for dickcissels (DICK), eastern meadowlarks (EAME), and grasshopper sparrows (GRSP) at Homestead National Monument, Nebraska, USA, and Tallgrass Prairie National Preserve, Kansas, USA, in 2008 and 2009 and both years pooled together. Estimates are weight-averaged across all models in the confidence set (within 10% of the weight of the top model). Nest success is based on at 21d nesting cycle for dickcissels, 24d for eastern meadowlarks, and 20d for grasshopper sparrows.

Estimate	Year	DICK Homestead	DICK Tallgrass	EAME Tallgrass	GRSP Tallgrass
Sample size	2008	11 nests	19 nests	10 nests	10 nests
	2009	10 nests	12 nests	9 nests	10 nests
Daily nest survival	2008	0.95 (0.86-0.98)	0.80 (0.14-0.99)	0.99 (0.82-0.99)	0.96 (0.87-0.99)
	2009	0.95 (0.86-0.99)	0.93 (0.85-0.97)	0.90 (0.69-0.97)	0.89 (0.76-0.95)
	Pooled	0.96 (0.91-0.98)	0.88 (0.81-0.92)	0.94 (0.86-0.97)	0.94 (0.86-0.97)
Nest success	2008	0.34 (0.04-0.70)	0.01 (0.00-0.82)	0.71 (0.00-0.98)	0.44 (0.06-0.79)
	2009	0.37 (0.05-0.73)	0.22 (0.03-0.53)	0.07 (0.00-0.49)	0.10 (0.00-0.38)
	Pooled	0.39 (0.13-0.64)	0.06 (0.01-0.18)	0.22 (0.03-0.54)	0.29 (0.05-0.60)

No common model described the variation in nest survival among species (Table 4). However, temporal variables (nest age:  $\beta = 0.16$ , SE = 0.07; day in season:  $\beta = 0.006$ , SE = 0.02) and elements of vegetation density (VOR:  $\beta = -0.33$ , SE = 0.48; VOR heterogeneity:  $\beta = 1.12$ , SE = 0.71) appear to influence eastern meadowlark nest survival at Tallgrass. Vegetation functional group composition (woody cover:  $\beta = -1.08$ , SE = 1.35; grass cover:  $\beta = -0.03$ , SE = 0.03; litter cover  $\beta = 0.04$ , SE = 0.02; bare ground:  $\beta = 0.004$ , SE = 0.07) and temporal variable models (nest age:  $\beta = 0.13$ , SE = 0.08; day in season:  $\beta = 0.01$ , SE = 0.02) received the most weight of evidence, along with the null model, for grasshopper sparrow nest survival at Tallgrass. Nest survival and success estimates were consistent between years for dickcissels at Homestead and more variable between years for all three species at Tallgrass (Table 3). Dickcissel nest success pooled across years was higher at Homestead (39%) than at Tallgrass (6%). Eastern meadowlark (22%) and grasshopper sparrow (29%) nest success was higher than dickcissel nest success (6%) at Tallgrass.

Table 4. Generalized linear model selection results for target species nest survival at Homestead National Monument (Homestead), Nebraska, and Tallgrass Prairie National Preserve (Tallgrass), Kansas, USA, in 2008 and 2009. Models were evaluated in Program R using binomial family and a log-exposure link. See Appendix B for year-specific model selection results.

Model Structure	AIC <sub>c</sub> <sup>a</sup>	K <sup>b</sup>	ΔAIC <sub>c</sub> <sup>c</sup>	w <sub>i</sub> <sup>d</sup>
Dickcissels at Homestead (21 nests, 73 observations)				
Null model	64.83	2	0.00	0.49
Woody <sup>e</sup> + forb <sup>f</sup> + grass <sup>g</sup> + litter <sup>h</sup>	66.02	6	1.18	0.27
Nest height <sup>i</sup> + distance to edge <sup>j</sup> + burn year <sup>k</sup>	68.84	8	4.01	0.07
VOR <sup>l</sup> + VOR heterogeneity <sup>m</sup>	68.95	4	4.12	0.06
Nest age <sup>n</sup> + day in nesting season <sup>o</sup>	69.17	4	4.34	0.06
VOR + VOR heterogeneity + woody + forb + grass + litter	69.57	8	4.73	0.05
Dickcissels at Tallgrass (30 nests, 73 observations)				
Null model	88.99	2	0.00	0.55
Nest height + distance to edge + burn year	91.26	7	2.27	0.18
VOR + VOR heterogeneity	91.88	4	2.89	0.13
Woody + forb + grass + litter	92.94	5	3.96	0.07
Nest age + day in nesting season	93.07	4	4.08	0.07
VOR + VOR heterogeneity + woody + forb + grass + litter	99.07	8	10.08	0.00
Eastern Meadowlark at Tallgrass (19 nests, 50 observations)				
Nest age + day in nesting season	50.44	4	0.00	0.48
VOR + VOR heterogeneity	52.47	4	2.02	0.18
Null model	52.76	2	2.32	0.15
VOR + VOR heterogeneity + grass + litter + bare <sup>p</sup>	53.78	7	3.34	0.09
Grass + litter + bare	53.89	5	3.45	0.09
Distance to edge + burn year	57.78	5	7.34	0.01
Grasshopper Sparrow at Tallgrass (20 nests, 53 observations)				
Woody + grass + litter + bare	49.37	6	0.00	0.27
Null model	49.53	2	0.15	0.25
Nest age + day in nesting season	49.66	4	0.28	0.24
VOR + VOR heterogeneity + woody + grass + litter + bare	51.18	8	1.81	0.11
VOR + VOR heterogeneity	51.71	4	2.33	0.08
Distance to edge + burn year	52.87	5	3.49	0.05

<sup>a-d</sup> AIC<sub>c</sub> = Akaike's Information Criterion adjusted for small sample sizes; K = number of model parameters; ΔAIC<sub>c</sub> = relative AIC<sub>c</sub>; w<sub>i</sub> = Akaike weight

<sup>e-h,p</sup> woody = % woody ground cover; forb = % forb ground cover; grass = % grass ground cover; litter = % litter cover; bare = % bare ground

<sup>i-k</sup> ht = height of nest rim above the ground; edge = average distance to edge; BY = years since last burn

<sup>l-m</sup> VOR = average visual obstruction reading, VOR.het = VOR heterogeneity

<sup>n-o</sup> age = number of days since the start of incubation; day = number of days since May 1

## DISCUSSION

Each of my sites was unique in avian community composition. Species richness was greater at the two smaller sites, but Tallgrass (the large site) was utilized by the most grassland obligate species for nesting (Table 1). The greatest number of BBS grassland obligate species was observed at Pipestone (the medium site) and the fewest was observed at Homestead (the small site). The species that occurred at the highest density differed among sites and few grassland obligate species occurred at all three sites (Table 2). Nest survival was extremely variable between years at Tallgrass (Table 3) and highest at the small site, Homestead.

### *Tallgrass Prairie National Preserve*

Tallgrass, the large, most southern site, had the lowest species richness. However, we observed the highest number of nesting obligate species at the preserve (Table 1). All four target species were observed at Tallgrass and three were observed nesting. We observed all expected species and, in addition to expected species, greater-prairie chicken, Henslow's sparrow, northern harrier, and western meadowlark. Greater-prairie chicken and Henslow's sparrow are considered species of continental conservation concern (Rich et al. 2004). HTLN long-term monitoring at Tallgrass has recorded greater prairie-chicken, along with dickcissel and grasshopper sparrow, among six species of breeding birds occurring consistently at Tallgrass (Peitz et al. 2010). They also identified Henslow's sparrow, along with eastern and western meadowlarks, as sensitive to subtle changes in grassland conditions.

Nest success estimates for eastern meadowlark (22%) and grasshopper sparrow (29%) were consistent with estimates reported by Frey et al. (2008) in their study of nesting in the tallgrass prairies of Kansas and Oklahoma (eastern meadowlark: 23%; grasshopper sparrow: 27%). My estimate of dickcissel nest success at Tallgrass (6%) was lower than their estimate (22%). However, Frey et al. (2008) concluded that dickcissel daily nest survival was influenced by vegetation density at the nest site and time of season, and they estimated that nest success could be as low as 6.5% at sites with low vegetation density (~2.5dm). Average VOR measurements at Tallgrass for both years (Fig. 1) was 1.3dm, with measurements as high as 7.5dm. However, my model selection results (Table 4) suggested that the standard set of vegetation covariates that I measured at nests do not affect dickcissel nest survival at Tallgrass. Variation in predator density or parasitism rates across the property (Johnson & Temple 1990; Winter et al. 2005) could also be affecting nest survival. Nonetheless, my target species appear to be nesting successfully at Tallgrass.

#### *Pipestone National Monument*

My medium-sized site, Pipestone (82 ha of prairie), also the most northerly site, had the most number of bird species utilizing prairie habitat for nesting and had the highest species richness (Table 1). Helzer and Jelinski (1999) concluded that grassland bird species richness is maximized when patches are >50ha – the size of Pipestone. Eight of 10 expected obligates were observed at Pipestone, plus three additional species not observed on the BBS route. One of the expected species that was absent, eastern meadowlark, prefers areas with tall grass and relatively little woody vegetation (Lanyon

1995). Pipestone has riparian areas passing through the center of the property (Fig. 2, Appendix B) and woody cover on the prairie was generally higher than my other sites (Fig. 2b). Removal of woody cover might increase the attractiveness of this property to species such as meadowlarks, but these riparian areas are of cultural and historical importance. Considerations of cultural and historical uses limit the extent to which a property the size of Pipestone might benefit grassland birds with larger territories. Nonetheless, long-term monitoring data show that Pipestone appears to have sufficient numbers of some grassland species, such as bobolink and ring-necked pheasant, to be beneficial as breeding habitat (Peitz 2010b).

Pipestone appears to be large enough to attract a considerable portion of the grassland obligate species pool from the local area. However, we observed only two species of grassland obligates nesting at Pipestone, indicating that many of the obligate species observed are utilizing the property for other reasons. If birds are utilizing the property for foraging but not as nesting substrate, Pipestone managers could consider managing for insects these birds feed on. It is also important to determine on what other properties these birds are nesting, such as the adjacent state wildlife management area, so that conservation within the NPS property's border is linked with conservation across borders. My data provides an example of a situation, which may be common at small parks, where survey data alone may fail to provide evidence of the lack of nesting on the property. At Pipestone, some obligate non-nesters, including western meadowlark and savannah sparrow (*Passerculus sandwichensis*), were observed in numbers sufficient to obtain density estimates (Table 2). The discovery that many birds were not nesting at

Pipestone should be important to future management decisions. Similar monitoring, at regular intervals, should be used in the future, and the park could consider enlisting the help of citizen scientists to monitor breeding behavior. Such monitoring would be cost effective and would engage the community in conservation efforts.

#### *Homestead National Monument*

Homestead, the small site, had the least number of species nesting in the grassland, the least number of obligates, and only one obligate species nesting on the property (Table 1). This result is not surprising given that many studies have found grassland birds to be negatively affected by small patch sizes (i.e., Helzer & Jelinski 1999; see Johnson 2001). Eastern and western meadowlarks, target species not observed nesting at Homestead, have large territories and tend to avoid extensive woody encroachment (Lanyon 1995; Davis & Lanyon 2008). Homestead has more woody vegetation (Fig. 1c) than the large site, Tallgrass (Fig. 1a), where meadowlarks were abundant. One expected species (according to BBS data) that was not observed at Homestead was upland sandpiper. It too requires large grasslands to accommodate its large territory sizes and prefers little woody cover and moderate grass cover (Poole 2005). It is unlikely that Homestead is large enough to support the large territories of many grassland birds, and conservation efforts should focus on birds that require less area for breeding, such as the dickcissel.

Dickcissels were abundant at Homestead (Table 2). They prefer locations with tall, dense vegetation with high forb content (Temple 2002) such as Homestead (Fig. 1 and 2c). Dickcissel nest success was relatively high (39%); Churchwell et al. (2008)

reported estimates 15%-30% from a tallgrass prairie in Oklahoma. I was unable to identify variables affecting nest success (Table 4). According to HTLN long-term monitoring, brown-headed cowbird was the most common species at the monument (Peitz 2010a). Other factors that affect predation (Winter et al. 2005) and parasitism (Johnson & Temple 1990), including a high proportion of woody edges, high predator density, high nest density, or high brown-headed cowbird density, may be affecting nest success at Homestead. Nonetheless, dickcissels are a species of conservation concern (Peitz 2010a), and they appear to be breeding productively at Homestead. Therefore, managers at Homestead could focus their management efforts on a few species, such as dickcissels, and continue long-term monitoring of grassland birds in general to detect any improvements or declines in the use of the property due to changes in management.

#### *Site Comparison*

Conducting an among-site comparison of grassland bird demographics at NPS properties in three states is problematic because few species occur at all three locations. Based upon my results of obligate species richness, obligate densities, and the number of nesting obligates, Tallgrass appears to have the highest capacity to benefit a large suite of grassland birds simultaneously. This result is not surprising given its large size, grassland vegetation homogeneity, and location within a contiguous grassland landscape. Vickery et al. (1994) argue that patches must be >200 ha to adequately support a diverse grassland bird community. Pipestone and Homestead are smaller than 200 ha and appear to be capable of successfully supporting only one or two species. Dickcissels are breeding successfully at Homestead and bobolink are nesting at Pipestone, and both are



species of conservation concern. Therefore, grassland songbird conservation and management should not be ignored or discounted at these sites.

Although the number of nesting grassland obligates was higher at the largest site, bird densities showed no clear pattern according to site size. The species that were at the highest densities were different among my sites, but even the small sites had at least one grassland obligate species that was among the most dense birds (Table 2). Annual variation in density estimates and the presence or absence of some grassland obligate species from year to year demonstrates the inherent dynamic nature of grassland ecosystems (Wiens 1973). Igl and Johnson (1997) found grassland bird species composition was similar from year to year but abundance and frequency changed considerably between years among species. Nest success estimates for all target species at Tallgrass also varied greatly among years (Table 3). The variation in bird densities and nest success in my study sites highlights the danger in making management decisions based on only one or two years of data. Long-term monitoring of nest success at my sites is needed to establish an estimate of among year variation in nest success.

Although my data only represent two years, the pattern of stochasticity and annual variation in densities is consistent with the findings of others. As a result, it is difficult to draw causal explanations based on abundance or density alone. Within the context of considerable annual variation, a long-term landscape level comparison of grassland birds among sites under different management regimens would help elucidate the affect of management decisions at these sites (Ribic & Sample 2001). But such studies are currently not within the capacity of the management at my study sites.

*Adaptive Management*

The strength of adaptive management is that it is a method that can be used despite the uncertainty that comes from gaps in knowledge about species of concern and their interactions with the environment. Adaptive management permits the continuation of management in such situations, while learning about the dynamics of the ecosystem continues through long-term monitoring and management experiments (Holling 1978; Walters 1986). Large sites like Tallgrass provide an ideal opportunity to assess the effects of different management practices on management goals within one property unit. For example, if managers hypothesized that increasing forb cover at Tallgrass would increase nest success for dickcissels, they could implement different burning and grazing regimens in different pastures on the property and monitor the changes in nest success and bird community structure over time. After a pre-determined number of years, they would re-evaluate the different regimens in conjunction with any changes in dickcissel conservation status, the status of other species of concern, or management resources. Management decisions at smaller sites can more readily be compared with other managed and unmanaged sites within the same region due to limitations in property size. In this way, management effects can be assessed apart from difference in avian community and vegetation structure among sites.

Due to the variability in vegetation preference among grassland obligate species, burning and/or grazing regimens that create a mosaic of grassland habitat will benefit the most species of grassland birds. Nevertheless, some grassland dependent species occur in low abundance or are absent from burned patches of grassland (Powell 2006). For small

sites, like Pipestone and Homestead, it is unlikely that there is sufficient area of land to develop a management plan that can benefit all grassland birds of concern. Therefore, small sites should focus management on species that consistently appear in sufficient numbers, such as dickcissels at Homestead or bobolinks at Pipestone. If many grassland birds are sensitive to patch size as other studies have found (Vickery et al. 1994; Helzer & Jelinski 1999; Winter & Faaborg 1999; Winter et al. 2006), it is unlikely that these smaller sites will be able to manage a large suite of grassland obligate birds.

My study has shown the value of enhancing long-term monitoring with a short-term, intensive effort to gather nesting information. Certainly, such information can be used in an adaptive management framework, to add to the information used to make management decisions (Herkert & Knopf 1998). But, the more important value of such intensive efforts may be to change the framework of a park's adaptive management system. That is, the information provided by intensive efforts may be used to modify a park's management goals and objectives. Specifically, my data suggest that managers at Pipestone and Homestead could modify their goals to focus on specific species, rather than the entire suite of avian grassland obligates. Such a shift will allow long-term monitoring data to be used effectively to guide decisions at individual units, which should support the park's overall goal of providing habitat for breeding birds in the Great Plains.

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### **Chapter 3 : USING STABLE ISOTOPES TO ASSESS FIDELITY OF GRASSLAND SONGBIRDS**

#### *Abstract:*

Management of grasslands as breeding habitat for songbirds has become high priority in North America given the level of habitat loss and alteration. National Park Service (NPS) properties on the Great Plains provide grassland bird breeding habitat, but more information is needed about the quality of this habitat. One way to monitor nest success, an element of habitat quality, is to monitor site fidelity. Intrinsic stable isotope markers are a promising alternative to inadequate extrinsic markers for tracking small birds over years. I measured grassland songbird site fidelity using stable isotopes ( $\delta D$ ,  $\delta^{13}C$ ,  $\delta^{15}N$ ) at three NPS properties (Pipestone National Monument, Homestead National Monument, Tallgrass Prairie National Preserve) in 2008 and 2009. To determine fidelity (proportion of local birds that return to breed) a measurement of 'local' isotope signature range is needed. I compared a new technique using range of  $\delta D$  from nestlings to assign adult disperser status to a standard isocline map technique, derived from growing season precipitation, to determine expected stable isotope values. I used blood and feather tissues, and I investigated discrimination factors between two tissues. The technique using nestlings as known origin birds yielded site-specific variances that are not available using the map lookup approach. Mean adult feather hydrogen ratios ( $\delta D$ ) were separable among study sites ( $P < 0.05$ ). Site fidelity was highest at the large site, Tallgrass (63%), and lower at the small site, Homestead (50%). Mean blood  $\delta D$  values were 46% more depleted than mean  $\delta D$  feather values. My technique of assigning origin offers a

promising alternative to the map lookup approach in stable isotopes studies. However, my approach is limited by the availability of nestling feathers. Analyzing multiple tissues from the same individual allow ecologists to use isotope values from multiple time scales to infer site fidelity. Managers considering using these techniques should consider landscape level management that incorporates these techniques into meeting specific management objectives.

## INTRODUCTION

Prairie ecosystems were once widespread across North America but have been drastically reduced, especially due to land conversion and habitat loss. Grassland birds, an integral part of prairie ecosystems, have experienced the most significant and consistent declines of any group of North American birds (Sauer et al. 2008). The need to maintain and manage remnant grasslands for grassland birds is becoming increasingly important as threats to their habitat continue (Samson & Knopf 1994). National Park Service (NPS) properties on the Great Plains provide breeding habitat for grassland birds. However, little is known about the quality of breeding habitat at these locations and more extensive study into grassland songbird breeding at these sites has been recognized as necessary (Powell 2000). High quality breeding habitats have characteristics that promote high nest success and productivity, and identifying habitats of high quality can focus conservation efforts where they will have the greatest impact. In the past, ecologists have focused on bird abundance as an indicator of habitat quality. However, low nest survival and success has been observed in areas with high abundance (Van Horne 1983; Vickery et al. 1992; Winter & Faaborg 1999). Avian ecologists have begun to focus more on productivity to identify higher quality breeding habitat (e.g., Vickery & Herkert 2001; Herkert et al. 2003; Churchwell et al. 2008). However, productivity data may be especially time consuming and expensive to collect in grassland systems, given the difficulty of locating and relocating nests that generally occur at low levels of density.

Avian ecologists may be able to avoid the difficulties of measuring productivity by assessing site fidelity, which may be an indicator of productivity. In many songbird

species, individuals that have bred successfully will return to the same location the following breeding season (Greenwood & Harvey 1982; Haas 1998). However, site fidelity has the potential to be even more difficult to measure than productivity. Few methods exist that allow ecologists to follow any one songbird through the course of migration because current extrinsic markers do not work for small songbirds. Leg bands yield low returns for small migrant and radio-telemetry technology for tracking small songbirds over the course of a year is still limited (Jones et al. 2007; Hobson & Norris 2008). As a result, many ecologists have begun to use intrinsic markers, such as the ratios of stable isotopes of hydrogen ( $\delta\text{D}$ ), carbon ( $\delta^{13}\text{C}$ ), and nitrogen ( $\delta^{15}\text{N}$ ), to infer animal movement patterns (reviewed by Hobson 1999). The use of stable isotope analyses may allow biologists to measure fidelity more efficiently (Brewster 2009).

Stable isotope analyses have been successfully used to answer an assortment of migration and dispersal related questions in birds (Hobson 1999; Rubenstein & Hobson 2004; Hobson 2005). Stable isotope signatures of animal tissues reflect the signature of the environment where that animal derived its diet during the generation of that tissue, and many stable isotopes vary in naturally occurring geographic patterns. Metabolically inert tissues (such as feathers or hair) maintain an isotopic record of the location in which that tissue was grown. Most migrant songbirds molt their feathers after breeding on or near the breeding grounds (Hobson 1999). Therefore, feathers collected on the breeding grounds prior to molt represent the stable isotopic signature of the location where the bird bred the preceding year. Metabolically active tissues (such as blood) have a higher turnover rate and carry the signature of the bird's diet over the last few days (Hobson &

Clark 1993). Comparing tissues within the same bird can track individuals at different time scales, but few ecologists have use multiple tissues in this manner (but see Hobson & Clark 1992; Hobson 1993; Clark et al. 2006). To my knowledge, none has used tissues as metabolically different as blood and feathers to investigate movement at varying time scales.

The success of using stable isotopes to determine the origin of a bird using tissue samples is dependent on appropriately assigning an individual bird to a location by comparing the isotopic signatures of the tissue and the location. This is known as the ‘assignment problem’ (Royle & Rubenstein 2004). Defining origin for stable isotope values collected from animal tissues is complicated by discrimination factors (the difference between the stable isotope values of an animal’s tissue and that of its diet, denoted by  $\Delta$ ) that are in turn altered by stress level, body size, and physiological difference among taxa (reviewed by Rubenstein & Hobson 2004; Martinez del Rio et al. 2009). Frequently, ecologists use isocline maps to assign individual birds of unknown origin to a given location (hereafter ‘the map approach’). A common method for hydrogen is to derive an expected tissue value for a location by adjusting  $\delta D$  values by a standard discrimination factor based on an average weighted growing season  $\delta D$  precipitation map (first published by Hobson & Wassenaar 1997). However, these maps are based upon kriging and interpolation methods from samples that are not uniformly distributed across North America, and regions such as the Great Plains are underrepresented (Fig. 1).



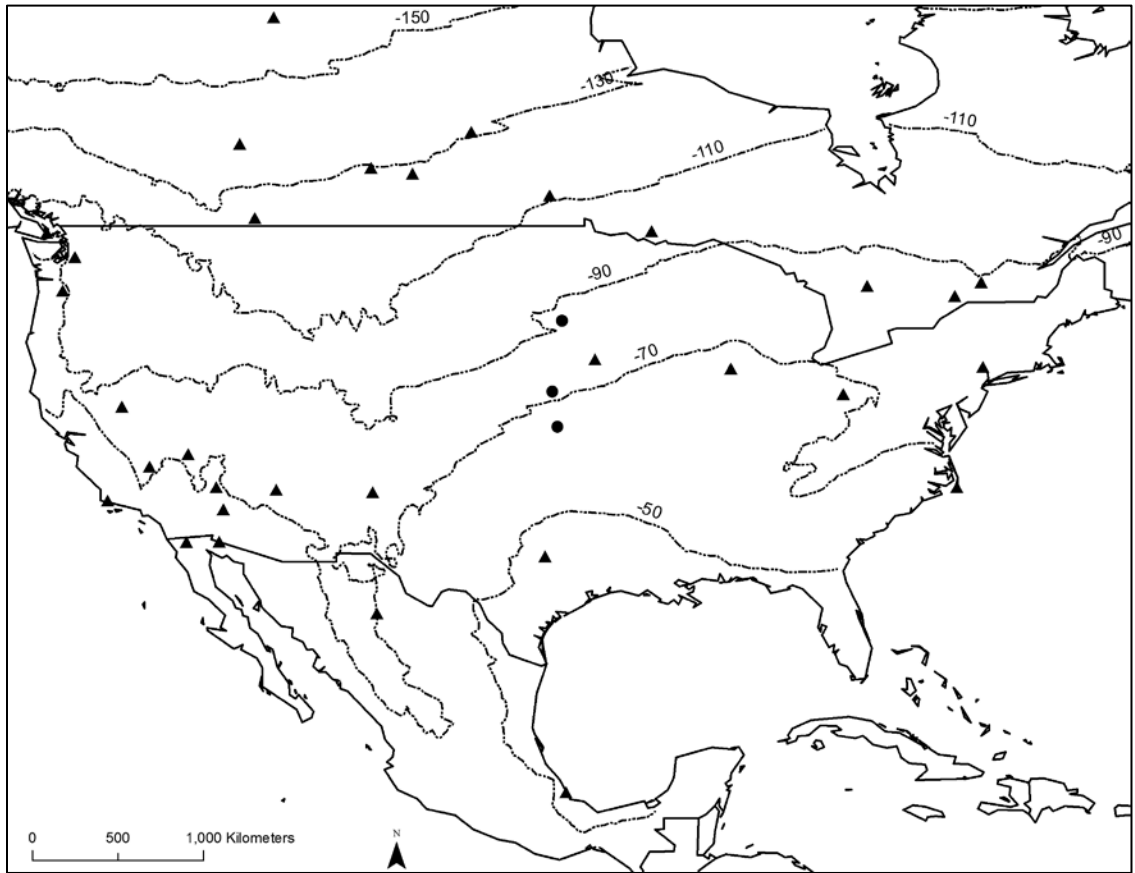


Figure 1. Isoclines of predicted feather  $\delta D$  values based on a standard -25‰ adjustment of weighted average growing season precipitation values after Hobson and Wassenaar (1997). Study sites (circles) are located in a region with few precipitation measuring sites (triangles). Growing season precipitation values from Bowen (2009).

To study birds in an underrepresented area, I either had to accept the assumption that this map accurately represents the isoclines across this region or utilize another method. A more accurate and species-specific method to define origin is to derive a baseline of location specific stable isotope values by measuring the signature of tissues from known origin birds, usually previously banded adults or flightless juvenile birds (Szymanski et al. 2007). However, this method is hindered by the problem of low band returns in small songbirds. I believe that the use of flightless juveniles known to have

derived their diet from a limited location (hereafter ‘the nestling approach’) should be a promising alternative, because nestlings represent birds of known origin (Smith & Dufty 2005; Wunder et al. 2005).

The goal of my study was to evaluate the efficacy of using stable isotope analyses to monitor site fidelity and habitat quality for grassland songbird conservation and management at Great Plains NPS properties. To assess this technique, I (1) evaluated the precision of using nestlings as known origin reference points for each site to compare this method with using the map lookup approach for assignment, (2) determined the proportion of returning breeders to dispersers at each study site to ascertain site fidelity estimates, (3) compared  $\delta D$ ,  $\delta^{13}C$ , and  $\delta^{15}N$  in feather and blood of nestlings to establish discrimination levels between tissues, and (4) compared the variances among multiple tissues and among adults and nestlings to demonstrate the differences in time scale at which each age group synthesized their feathers and blood.

I expected nestling stable isotope values to be more locally robust and site-specific than adjusted precipitation map values. Therefore, fewer birds should be assigned as dispersers using the nestling approach than the map approach. I expected the largest NPS property, where the prairie is contiguous and surrounded by grazing pastures, to have the highest quality habitat and smaller sites, where the prairie is an island of grassland habitat among row crops, to have lower quality habitat. Site fidelity should be higher at locations with higher quality habitat (*i.e.*, at the largest site). I expected  $\delta D$  to be the most useful stable isotope for distinguishing among sites due to the strong latitudinal gradient in this isotope. The stable isotope signatures in blood are developed

over a short period of time and I expected blood stable isotope values of both adults and nestlings to have a similar variance. I expected adult feather values to have greater variance than nestling feather values because adults will have grown their feathers the previous year (potentially at a variety of breeding areas) and nestlings should have grown their feathers only at the current breeding site.

## METHODS

### STUDY SITES

My study was conducted during May - August of 2008 and 2009 at three National Park Service (NPS) properties: Homestead National Monument in Nebraska (65 ha), Pipestone National Monument in Minnesota (114 ha), and Tallgrass Prairie National Preserve in Kansas (4395 ha). Hydrogen isotope ratios ( $\delta D$ ) vary latitudinally in a predictable pattern across North America (Hobson & Wassenaar 1997) and my sites lay along a north-south gradient (across  $\sim 5^\circ$  of latitude) with  $0.33^\circ$  of longitudinal variation. Stable-carbon isotopes ( $\delta^{13}C$ ) vary with the proportion of  $C_3$  forbs and  $C_4$  grasses in an animal's diet (Tieszen et al. 1983) and with latitude and altitude (reviewed by Rubenstein & Hobson 2004). Stable-nitrogen isotopic ( $\delta^{15}N$ ) concentrations in surface waters show a positive pattern with the intensity of agricultural practices (Hebert & Wassenaar 2001) and become heavier with increasing trophic level (Minagawa & Wada 1984). Pipestone National Monument (hereafter Pipestone) contains 82 ha of tallgrass prairie and is surrounded by private land, row crops, the city of Pipestone, and a state wildlife management area. Homestead National Monument (Homestead) contains 36 ha of prairie, and is surrounded by row crops and suburban neighborhood. Tallgrass Prairie

National Preserve (Tallgrass) contains 4,395 ha of tallgrass prairie and is surrounded by rangeland. Tallgrass is composed of two sections (west: 3,036 ha; east: 1,359 ha), and I selected sampling sites in the western portion of Tallgrass. I avoided areas of Pipestone where Native American ceremonies were performed and where a population of the threatened western prairie fringed orchid (*Platanthera praeclara*) was located. Sections of Pipestone and Homestead are burned rotationally once every three years. Tallgrass is grazed by cattle annually and burned rotationally every 2-3 years. All mist netting efforts were focused around 30-50 grassland survey points randomly placed at each study site by the Heartland Monitoring Network. This design, with a similar number of study points at each site, enables scaling experiments to the size of the park unit (Horn et al. 2000).

## STUDY SPECIES

Lichtenberg and Powell (2000) and Powell (2000) reported that dickcissels (*Spiza americana*), grasshopper sparrows (*Ammodramus savannarum*), and western and eastern meadowlarks (*Sturnella neglecta*, *Sturnella magna*) were among the most abundant birds at my study sites. Each of these species has declined significantly in the study area during 1966-2007 (Sauer et al. 2008). I selected these as target species for my analyses. These species molt their feathers on or near the breeding grounds shortly after breeding (Pyle 1997). Feathers are metabolically inert, retaining the stable isotopic signature of the bird's diet during feather generation (Hobson 1999). In this way, the stable isotopic signatures of feathers collected from my target species represent the location of each individual during the previous breeding season.

## SAMPLING METHODS

### *Feather and Blood Sample Collection*

My field assistants and I captured target species birds in mist nets (Institutional Animal Care and Use Committee permit #07-09-043D) during May to August and aged individuals based on plumage characteristics, as suggested by Pyle et al. (1997). We banded each bird with an aluminum U.S. Fish and Wildlife band (banding permit #23143). We plucked the right, outer-most retriix from each bird for use in stable isotope analysis (scientific collection permits were obtained from each state). Plucking the feather allows feather regeneration to proceed faster than clipping. Each feather was stored in an individual, labeled envelope. We attempted to fill two 70 $\mu$ L capillary tubes with blood from the brachial artery using a sterile lancelet, and we emptied the capillary tubes into an individually labeled microcentrifuge tube. The collection site was sterilized with alcohol before and after collection, bleeding was stopped using light pressure and a cotton ball, and the wound was sealed using a small amount of surgical adhesive. Each tube of blood was stored in a cooler until it could be frozen at the end of the day. The blood was later dried in a freeze drying oven (-40° C) and with paraffin wax to keep out ambient moisture. We located grassland bird nests by searching systematically (Davis 2005) and observing adult behavior. We weighed and banded nestlings before they fledged from the nest. Feather and blood samples were taken using the same protocols as adults, but we removed the largest growing wing feather because retriix feathers were too small for adequate samples.

*Laboratory Preparation and Analysis*

Feathers were cleaned in a 2:1 chloroform:methanol solvent rinse and feathers and blood were prepared for  $\delta D$  analysis at the National Water Research Institute in Saskatoon, Canada. Keratin standards were used to correct for uncontrolled isotopic exchange between samples and ambient water vapor. Stable hydrogen isotope measurements on feathers and keratin standards were performed on  $H_2$  derived from high-temperature flash pyrolysis of feathers and continuous-flow isotope-ratio mass spectrometry (CF-IRMS). Pure  $H_2$  was used as the sample analysis gas and the isotopic reference gas. A Eurovector 3000<sup>TM</sup> (Milan, Italy) high temperature elemental analyzer (EA) with autosampler was used to automatically pyrolyze feather samples to a single pulse of  $H_2$  gas. The resolved  $H_2$  sample pulse was introduced to the isotope-ratio mass spectrometer (Micromass Isoprime<sup>TM</sup> with electrostatic analyzer, Micromass, Manchester, UK) via an open-split capillary. Repeated analysis of hydrogen isotope intercomparison material IAEA-CH-7 (-100‰) was routinely included as a check to eliminate variation due to isotope exchange with ambient water vapor. Reported  $\delta D$  values, in parts per thousand (‰), are equivalent to non-exchangeable hydrogen and were normalized on the Vienna Standard Mean Ocean Water-Standard Light Antarctic Precipitation (VSMOW-SLAP) standard scale. Based on long-term measurements of intercomparison material, the laboratory's estimate for laboratory error is  $\pm 1.5\text{‰}$  for  $\delta D$ .

Stable-carbon and nitrogen isotope assays were performed on 1-mg sub-samples of powdered material at the stable isotope facility of the Department of Soil Science, University of Saskatchewan. Samples were first loaded into tin cups and combusted in a

Robo-Prep elemental analyzer at 1200° C. The resultant CO<sub>2</sub> and N<sub>2</sub> gases were separated and analyzed using an interfaced Europa 20:20 continuous-flow isotope ratio mass spectrometer, with every fifth sample separated by two (albumin) laboratory standards. Results are reported in delta notation in parts per thousand (‰) relative to Air ( $\delta^{15}\text{N}$ ) and VPDB ( $\delta^{13}\text{C}$ ). Based on replicate measurements of albumin standards, measurement precision (SD) for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values was estimated to be  $\pm 0.1\text{‰}$  and  $\pm 0.3 \text{‰}$ , respectively.

## STATISTICAL ANALYSIS

### *Assignment of Origin*

I used two techniques to establish the proportion of adult birds that were returning to each study site to breed (i.e., ‘local birds’) and compared the site fidelity estimates from each of these techniques. For the first technique, the nestling approach, I used the range of  $\delta\text{D}$  values from nestling feathers for each site as the range of expected values for that site’s local adult birds. Adult  $\delta\text{D}$  feather measurements outside of the nestling  $\delta\text{D}$  feather range for each site were considered to be dispersers and measurements within the range were considered to be local birds.

The second technique I used to assign origin was ‘the map approach’. I used growing season precipitation maps to obtain expected  $\delta\text{D}$  feather values (after Hobson and Wassenaar 1997). I used GIS-based maps produced by Bowen (2009) to obtain an estimated  $\delta\text{D}$  precipitation value for each site. I adjusted the precipitation value for each site by a discrimination factor of  $-25\text{‰}$  (Wassenaar & Hobson 2000) to account for the

change to the site's  $\delta D$  precipitation value as it is incorporated into the bird's feathers. I used a  $\pm 6\%$  confidence interval for these adjusted  $\delta D$  precipitation values based on the range of model uncertainty for interpolation given by Bowen et al. (2005). Adult  $\delta D$  feather values not within  $\pm 6\%$  of the expected adjusted  $\delta D$  precipitation value of each site were considered to be dispersers according to the map approach (Wunder & Norris 2008).

### *Site Fidelity*

I used analysis of variance (ANOVA) to test for differences in  $\delta D$ ,  $\delta^{13}C$ , and  $\delta^{15}N$  feather and blood values among locations. I used nestling feathers at Tallgrass to test for species and year effects by comparing means using Tukey's honest significant difference test. Feathers are the most commonly used tissue for isotopic analyses of songbird movement, and nestling samples for three of the four target species were sufficiently large at Tallgrass for these analyses. I pooled species and years within each age class (adult and nestling) within each location for subsequent analyses when my initial analyses indicated no effect of species or year for nestlings at Tallgrass. I used ANOVA to determine whether nestling feather means were distinguishable among locations at  $\alpha=0.05$ . If nestling feathers were distinguishable, I assumed that means for adult feathers at all three locations should be distinguishable when site fidelity is 100%. I used Program R (R Development Core Team 2008) to conduct all statistical tests.

### *Tissue Comparisons*

To describe the differences in discrimination rates between the two tissues collected, I ran simple linear regressions of nestling feathers and blood for each of the



three stable isotopes. I used ANOVA to compare means of adult blood and nestling blood at  $\alpha=0.05$  within each study site. I used Fligner-Killeen test for homogeneity of variances to compare the variances of feather and blood values among the two age groups at each site. I used Shapiro-Wilk to test for normality in model residuals for all ANOVA comparisons.

## RESULTS

I gathered 21 adult samples from Pipestone, 72 adult and 6 nestling samples from Homestead, and 60 adult and 30 nestling samples from Tallgrass (Table 1). Pipestone stable isotope results include bobolinks (*Dolichonyx oryzivorus*; n=9), western meadowlark (n=1), dickcissel (n=8), and grasshopper sparrow (n=3). Homestead samples include dickcissel (n=71), and eastern meadowlark (n=2). Samples from Tallgrass include dickcissel (n=17), eastern meadowlark (n=12), and grasshopper sparrow (n=31). Nestling samples included brown-headed cowbird (*Molothrus ater*; n=3), dickcissel (n=11), eastern meadowlark (n=17), and grasshopper sparrow (n=6).  $\delta D$  was the most variable stable isotope measured among locations based upon ANOVA mean comparisons (Fig. 2). Nestling feathers at Tallgrass did not vary by species or year in values of  $\delta D$  (species:  $F_{3, 25}=0.324$ ,  $P=0.808$ ; year:  $F_{1, 25}=0.130$ ,  $P=0.722$ ) or  $\delta^{15}N$  (species:  $F_{3, 20}=0.619$ ,  $P=0.611$ ; year:  $F_{1, 20}=0.013$ ,  $P=0.909$ ), while nestling feather values of  $\delta^{13}C$  tended to vary by species ( $F_{3, 20}=2.925$ ,  $P=0.059$ ) and year ( $F_{1, 20}=4.347$ ,  $P=0.050$ ). However, Tukey's HSD test showed no differences among  $\delta^{13}C$  feather value mean comparisons according to species or years ( $P \geq 0.071$  for all comparisons).

Table 1. Isotopic composition of  $\delta\text{D}$ ,  $\delta^{13}\text{C}$ , and  $\delta^{15}\text{N}$  in feathers and blood of grassland songbirds in 2008 – 2009 at Pipestone National Monument (P), Minnesota, Homestead National Monument (H), Nebraska, and Tallgrass Prairie National Preserve (T), Kansas, USA.

	Adult Feathers			Adult Blood			Nestling Feathers			Nestling Blood		
	P	H	T	P	H	T	P	H	T	P	H	T
$\delta\text{D}$												
$\bar{x}$	-65.9	-52.9	-42.4	-119.6	-96.8	-87.5	- <sup>a</sup>	-62.7	-50.5	-	-100.9	-85.3
SD	19.9	10.6	14.8	7.5	6.3	8.3	-	11.9	8.1	-	5.2	7.5
SE	4.4	1.2	2.0	1.8	0.8	1.4	-	4.9	1.5	-	3.0	1.7
n	21	72	60	18	55	38	0	6	30	0	3	19
$\delta^{13}\text{C}$												
$\bar{x}$	-17.1	-18.7	-16.8	-24.0	-21.0	-19.9	-	-20.7	-17.4	-	-21.6	-19.8
SD	4.5	4.4	3.6	1.4	2.3	2.0	-	2.6	2.7	-	2.1	1.9
SE	1.0	0.5	0.5	0.3	0.3	0.3	-	1.2	0.5	-	1.2	0.5
n	21	69	60	18	54	36	0	5	25	0	3	16
$\delta^{15}\text{N}$												
$\bar{x}$	8.3	8.7	6.9	7.2	6.7	4.8	-	6.7	4.5	-	4.6	4.7
SD	2.3	2.3	3.2	1.4	1.9	1.2	-	1.8	2.0	-	1.0	1.8
SE	0.5	0.3	0.4	0.3	0.3	0.2	-	0.8	0.4	-	0.6	0.5
n	21	69	60	18	54	36	0	5	25	0	3	16

<sup>a</sup> No nestling feather or blood samples were collected from target species at Pipestone

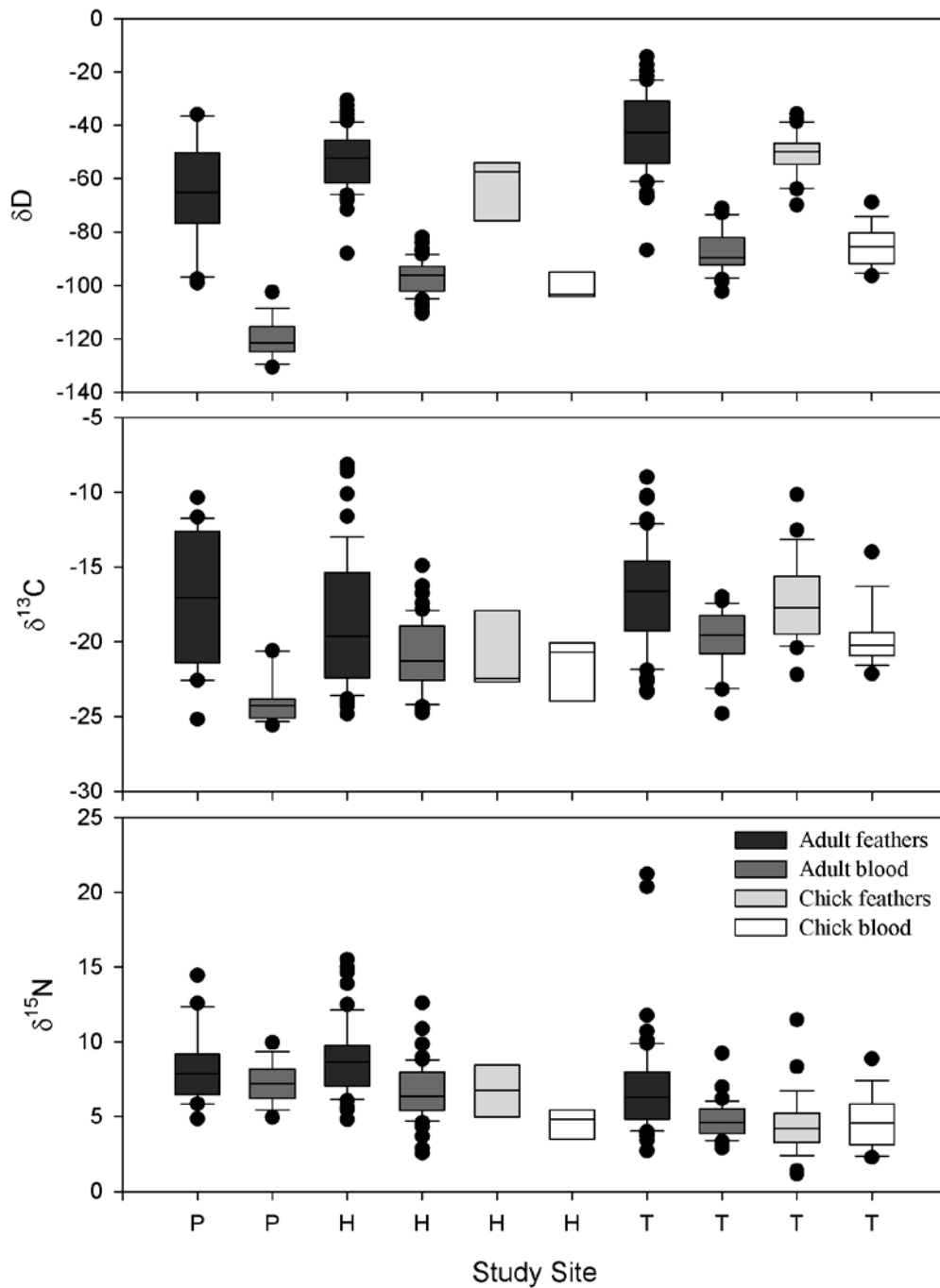


Figure 2. Distribution of  $\delta D$ ,  $\delta^{13}C$ , and  $\delta^{15}N$  values for adult and nestling feather and blood samples collected from grassland songbirds at Pipestone National Monument (P), MN, Homestead National Monument (H), NE, and Tallgrass Prairie National Preserve (T), KS, USA, 2008-2009. Shown are median line (horizontal line in center of each box), 25<sup>th</sup> and 75<sup>th</sup> percentiles (ends of boxes), 10<sup>th</sup> and 90<sup>th</sup> percentiles (vertical lines), and outliers (closed circles).

### *Assignment of Origin and Site Fidelity*

Expected  $\delta D$  feather values (mean and range of values from nestlings) were  $-62.7\text{‰}$  (95% CI:  $-53.2\text{‰}$ ,  $-72.2\text{‰}$ ) and  $-50.5\text{‰}$  (CI:  $-47.6\text{‰}$ ,  $-53.3\text{‰}$ ) for Homestead and Tallgrass, respectively (Table 1). Expected  $\delta D$  feather values based upon adjusted precipitation map values were  $-61\text{‰}$  (95% CI:  $-55\text{‰}$ ,  $-67\text{‰}$ ),  $-46\text{‰}$  (CI:  $-40\text{‰}$ ,  $-52\text{‰}$ ), and  $-41\text{‰}$  (CI:  $-35\text{‰}$ ,  $-47\text{‰}$ ) for Pipestone, Homestead, and Tallgrass, respectively. A similar proportion of adults at Homestead ( $n=72$ ) were classified as ‘dispersers’ by using the range of nestling ( $n=6$ )  $\delta D$  feather values (50%, CI: 38%-62%) as by using adjusted map values (49%; CI: 37%-61%). I recaptured two 2008 banded birds at Homestead in 2009 and both were classified as local birds in 2008 and 2009 using either approach. Tallgrass adult  $\delta D$  feather values ( $n=60$ ) tended to have a lower proportion of dispersers (37%; CI: 25%-49%) using nestling  $\delta D$  feather values ( $n=30$ ) than adjusted map values (55%; CI 42%-68%). Eighty-three percent (5 of 6) nestling  $\delta D$  feather values from Homestead and 34% (10 of 29) from Tallgrass were incorrectly assigned as dispersers using the map approach. No nestling samples were available from Pipestone, so I used only adjusted map values to determine the proportion of outliers. Sixty percent (CI: 39%-81%) of Pipestone birds ( $n=20$ ) were classified as dispersers using the map method.

The ratios for each of the three isotopes varied between Homestead and Tallgrass nestlings’ feathers ( $\delta D$ :  $F_{1,34}=9.697$ ,  $P=0.004$ ;  $\delta^{13}C$ :  $F_{1,28}=6.381$ ,  $P=0.017$ ;  $\delta^{15}N$ :  $F_{1,28}=5.164$ ,  $P=0.031$ ). Differences among blood and feathers from the same location were largest in  $\delta D$  measurements (Fig. 2). Mean adult feather values differed by location for all three stable isotopes ( $\delta D$ :  $F_{2,150}=24.206$ ,  $P<0.001$ ;  $\delta^{13}C$ :  $F_{2,147}=3.597$ ,  $P=0.03$ ;

$\delta^{15}\text{N}$ :  $F_{2,147}=7.657$ ,  $P<0.001$ ). Means of  $\delta\text{D}$  values in feathers from adults were different among study sites in all Tukey's HSD comparisons ( $P<0.001$ ), but the only Tallgrass and Homestead differed in  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  in adult feathers ( $\delta^{13}\text{C}$ :  $P=0.031$ ,  $\delta^{15}\text{N}$ :  $P<0.001$ ).

### *Tissue Comparisons*

Differences between feathers and blood in nestlings were most pronounced in  $\delta\text{D}$ , with mean blood values 46.72‰ more depleted than mean feather values. For every 1‰ decrease in  $\delta\text{D}$  in nestling blood,  $\delta\text{D}$  nestling feather values decreased by 0.42‰ (Fig. 3a). I found less evidence for linear relationships between nestling blood and feather values for  $\delta^{13}\text{C}$  ( $P=0.121$ ) and  $\delta^{15}\text{N}$  ( $P=0.087$ ; Fig. 3b,c). Feather values of  $\delta^{13}\text{C}$  were more depleted than blood (Fig. 3b), while  $\delta^{15}\text{N}$  values of feathers and blood did not show evidence of differential depletion (Fig. 3c). Adult and nestling values of  $\delta\text{D}$  from blood were similar at Homestead ( $F_{1,56}=1.225$ ,  $P=0.273$ ) and Tallgrass ( $F_{1,55}=0.894$ ,  $P=0.349$ ). Likewise, values of  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  from blood were similar for adults and nestlings at both parks ( $\delta^{13}\text{C}$  Homestead:  $F_{1,55}=0.197$ ,  $P=0.659$ ;  $\delta^{13}\text{C}$  Tallgrass:  $F_{1,50}=0.010$ ,  $P=0.919$ ;  $\delta^{15}\text{N}$  Homestead:  $F_{1,55}=3.576$ ,  $P=0.064$ ;  $\delta^{15}\text{N}$  Tallgrass:  $F_{1,50}=0.079$ ,  $P=0.791$ ).

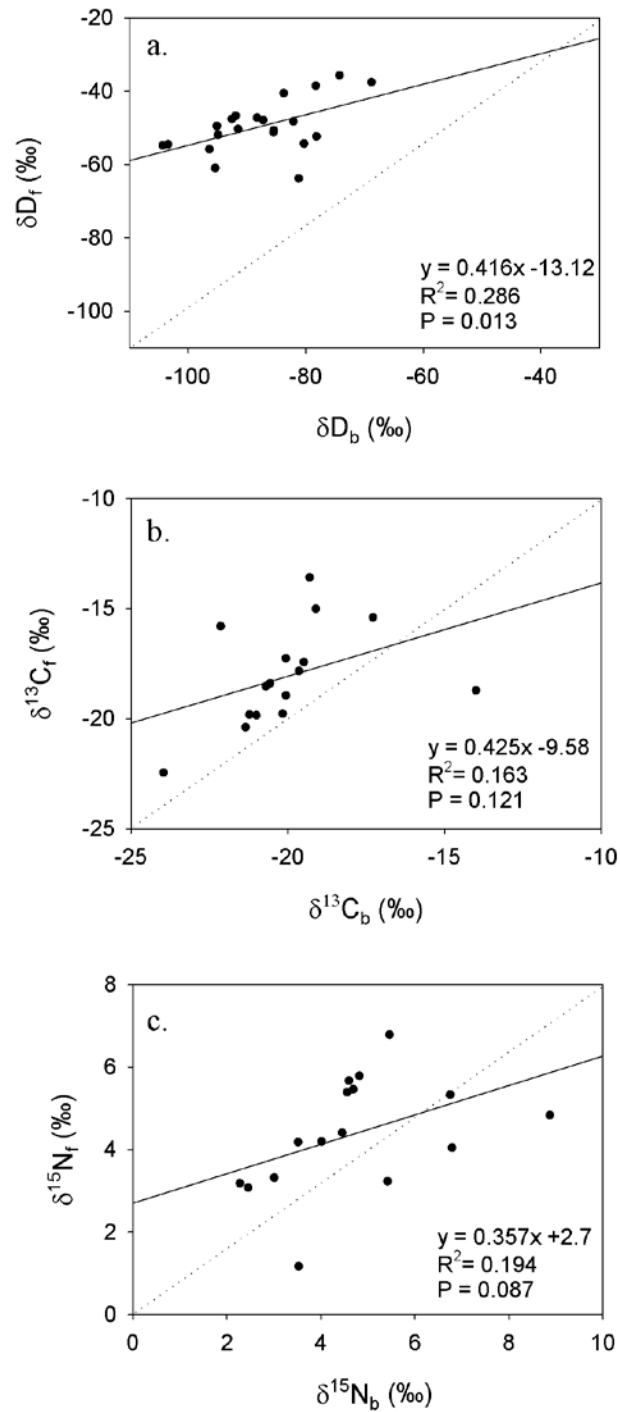


Figure 3. Relationship between feather ( $\delta X_f$ ) and blood ( $\delta X_b$ )  $\delta D$  ( $n=20$ ),  $\delta^{13}C$  ( $n=16$ ), and  $\delta^{15}N$  ( $n=16$ ) values in grassland songbird nestlings from Homestead National Monument, Nebraska, and Tallgrass Prairie National Preserve, Kansas, USA, 2008-2009. Dotted line represents 1:1 ratio.

Variances of values from adult and nestling blood were similar at Homestead ( $\delta\text{D}$ : adult  $\sigma^2=39.10$ , nestling  $\sigma^2=26.95$ ,  $P=0.439$ ;  $\delta^{13}\text{C}$ : adult  $\sigma^2=5.37$ , nestling  $\sigma^2=4.38$ ,  $P=0.514$ ;  $\delta^{15}\text{N}$ : adult  $\sigma^2=3.47$ , nestling  $\sigma^2=0.98$ ,  $P=0.207$ ) and Tallgrass ( $\delta\text{D}$ : adult  $\sigma^2=69.71$ , nestling  $\sigma^2=56.56$ ,  $P=0.622$ ;  $\delta^{13}\text{C}$ : adult  $\sigma^2=3.96$ , nestling  $\sigma^2=3.63$ ,  $P=0.146$ ;  $\delta^{15}\text{N}$ : adult  $\sigma^2=1.54$ , nestling  $\sigma^2=3.28$ ,  $P=0.214$ ). The variance in the values of isotopic ratios from adult and nestling feathers were not different at Homestead ( $\delta\text{D}$ : adult  $\sigma^2=112.2$ , nestling  $\sigma^2=142.48$ ,  $P=0.791$ ;  $\delta^{13}\text{C}$ : adult  $\sigma^2=19.02$ , nestling  $\sigma^2=6.90$ ,  $P=0.241$ ;  $\delta^{15}\text{N}$ : adult  $\sigma^2=5.35$ , nestling  $\sigma^2=3.35$ ,  $P=0.684$ ). Tallgrass adult and nestling feather variances tended to differ for  $\delta^{13}\text{C}$  (adult  $\sigma^2=12.64$ , nestling  $\sigma^2=7.23$ ,  $P=0.054$ ) and  $\delta^{15}\text{N}$  (adult  $\sigma^2=10.53$ , nestling  $\sigma^2=4.14$ ,  $P=0.052$ ). Variance of  $\delta\text{D}$  adult feathers values (adult  $\sigma^2=220.30$ ) was greater than  $\delta\text{D}$  nestling feather variance ( $\sigma^2=65.46$ ,  $P<0.001$ ) at Tallgrass.

## DISCUSSION

As expected, I found  $\delta\text{D}$  to be the most useful stable isotope for discriminating among study sites and  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  to be less useful. The nestling approach yielded expected  $\delta\text{D}$  feather values with site-specific variances, whereas the map approach yielded a symmetrical range of variance at all sites. Site fidelity, as assessed by using the nestling approach, tended to be highest at the largest study site, Tallgrass (63%). Discrimination factors for feather and blood samples were different for  $\delta\text{D}$  but not for  $\delta^{13}\text{C}$  or  $\delta^{15}\text{N}$  (Fig. 2). Nestling  $\delta\text{D}$  feather variance was smaller than adult  $\delta\text{D}$  variance at Tallgrass, while nestling  $\delta\text{D}$  feather variance did not differ from adult  $\delta\text{D}$  variance at Homestead. This is congruent with the smaller variance on expected feather values at

Tallgrass and larger variance on expected feather values at Homestead using the nestling approach.

### *Assignment of Origin*

My results demonstrate that using the nestling approach for songbird  $\delta D$  feather assignment is a preferable alternative to the map approach for grassland songbirds. One weakness in using the map approach is that it does not provide any intrinsic means to supply a range of expected  $\delta D$  values at a site. The true range of values may vary by taxa, species, or location (Hobson 2005). Variances for expected values must be assumed or gleaned from previous studies conducted at different locations or with different species (e.g., Royle & Rubenstein 2004). The expected range of  $\delta D$  values for local adults using nestling feather values was larger at Homestead and smaller at Tallgrass than the expected range generated by the map approach, demonstrating that variance are not the same among sites of interest. Therefore, some local Homestead birds were misclassified as ‘dispersers’ using the map approach while some dispersers from Tallgrass were misclassified as ‘local’ birds using the map approach. The map method also failed to correctly assign 83% of Homestead nestlings and 34% of Tallgrass nestlings as local birds.

A second limitation due to symmetrical variances in the map approach is the issue of distinguishing sites isotopically. The utility of any stable isotopic analysis is dependent upon the extent to which sites of interest can be distinguished by their isotopic signatures (Hobson et al. 2001). The map approach (with  $\pm 6\text{‰}$  range) suggested that the expected value of  $\delta D$  from feathers at Homestead and Tallgrass (200 km apart) would



overlap, which would mean that birds from my sites would not be isotopically distinguishable. Clark et al. (2006) employed the map approach in their analysis of lesser scaup (*Aythya affinis*) from widely separated sites from northwestern North America, and their  $\delta D$  feather values from these sites overlapped. Hobson et al. (2001) were unable to distinguish the signatures of their New England sites; however, they attribute this to the movement of birds among sites and not to the limitations of their precipitation map. Hobson & Wassenaar (1997) were able to distinguish among sites, but these sites ranged from as far south as Central America north to Alaska and not all sites were separable from all others. I was able to distinguish between my two sites with my sample of nestlings, demonstrating the benefit of using local data to make local inferences regarding avian fidelity.

A third limitation to the map approach is the requirement that growing season precipitation values be extrapolated using kriging techniques from a limited number of unevenly distributed sampling stations, and the resulting values must be adjusted to account for tissue discrimination factors. Hobson and Wassenaar (1997) extrapolated their map from growing season measurements at 39 sampling sites, only one of which was located in the Midwest near my study sites (Fig. 1). Over time, these maps may be improved by adding more sites, but they are still subject to the need for discrimination factor adjustments. Hobson (2005) suggests that the map approach -25‰ correction factor recommended for passerines (Wassenaar & Hobson 2000; Hobson et al. 2004) may not be applicable in some locales or may be different among taxa. Many more laboratory

experiments are needed to understand the relationship between the isotopic signature of diet and the signature of different bird tissues (Martínez del Río et al. 2009).

My method is an improvement on the map approach because it creates a site and taxa-specific range of values and requires fewer assumptions. However, my approach does assume that  $\delta D$  values from nestlings at each location accurately represent the  $\delta D$  values that have been obtained from local birds at the end of the previous year's molt. For example, local adult birds collected in 2009 carry the same isotopic signature as nestlings from 2008. As this range of values may change slightly from year to year due to changes in precipitation, a longer study (e.g., 3-5 yr) would provide more adult/nestling population pairs, and increase the accuracy of site-specific expected  $\delta D$  feather values.

Although the nestling approach negates the need to make the three assumptions above, it has some logistical limitations. One limitation of the nestling approach is the need for high numbers of nestling feathers. To achieve a confidence interval of  $\pm 10\%$  on site fidelity estimates from Homestead using the nestling method (50% site fidelity), 90 feathers would be needed. To achieve a  $\pm 6\%$  CI, 230 feathers would be needed. Grassland bird nests can be difficult to locate, and if the nests are not old enough to contain feathered nestlings, the nest will have to be relocated at a later date when nestlings will have begun to grow feathers. This limitation could be overcome to some extent by developing site-specific mean and variance for expected  $\delta D$  feather values over 3-5 yr and then re-evaluating that standard every 3-5 yr after that. A second alternative is to use 3-5 yr of nestling values to calibrate a reference standard developed from local

growing-season precipitation  $\delta D$  values. NPS properties interested in using this technique should consider alternatives that are within the scope of their management goals and resources.

### *Site Fidelity*

According to the nestling approach, site fidelity tended to be higher at Tallgrass (63%) and lower at Homestead (50%). Site fidelity tended to be lower at Tallgrass (45%) than Homestead (51%) using the map method. Both approaches yielded a similar number of dispersing adults at Homestead, although a different set of individuals was identified as dispersers. Most notably, 83% of Homestead nestling  $\delta D$  feather values and 34% of Tallgrass nestling  $\delta D$  feather values were incorrectly assigned as dispersers using the map approach. Site fidelity appeared to be lowest at Pipestone (40%). However, this low estimate may also be attributable to the incorrect assignment of individuals when using the map method. Site fidelity confidence intervals overlapped for all site fidelity estimates for both methods. My inability to distinguish among site fidelity estimates may be attributable to the resolution of stable isotope analysis; my sites may not be far enough apart for each site to represent distinct populations of breeding birds. Further study into the scale at which site fidelity estimates and populations of grassland songbirds can be distinguished is needed.

There are several hypotheses as to why site fidelity might occur in any given species at a site (Greenwood & Harvey 1982). Haas (1998) reported evidence from American robins (*Turdus migratorius*) and brown thrashers (*Toxostoma rufum*) to support the hypothesis that site fidelity is a response to breeding success the previous nesting

season. Bobolink, a grassland obligate species, had higher return rates at a high-quality site (70% for males) than at low-quality sites (44% for males; Bollinger & Gavin 1989). These results also supported the breeding success hypothesis. Return rates of grassland obligates in a study by Jones et al. (2007) were low (5-9%) and were attributed to migratory nomadism due to the stochastic nature of grassland habitat. However, their results may also be attributable to low re-observation rates of banded birds (5.3%). Savannah sparrow (*Passerculus sandwichensis*) return rates have been described at 45-50% (Bédard & LaPointe 1984; see Jones et al. 2007) and as high as 80% (Fajardo et al. 2009). Such variation in site fidelity estimates of grassland obligates begs the question what 'low' and 'high' site fidelity rates are. Perhaps instead of striving towards an 'ideal' site fidelity rate, it is more useful for NPS managers to establish the site fidelity rate at a reference site considered to be high quality (based upon productivity and fecundity estimates) and gauge site fidelity estimates at other sites by this reference (e.g., Bollinger & Gavin 1989). Tallgrass, with its large size, homogeneous grassland, and context within a grassland landscape, could serve as such a high quality reference site.

### *Tissue Comparisons*

Nestling  $\delta D$  feather and blood values were correlated for Tallgrass chicks (Fig. 3a). Clark et al. (2006) found a relationship between lesser scaup (*Aythya affinis*) duckling feathers and claws, so the relationship between tissues in my study was expected. Surprisingly, I did not find a significant relationship between  $\delta^{13}C$  feathers and  $\delta^{13}C$  blood values or between  $\delta^{15}N$  feather and  $\delta^{15}N$  blood in nestlings (Fig. 3). Many studies have found discrimination values to be variable between tissues for the same diet.

This is believed to be caused by a phenomenon called ‘isotopic routing’, where stable isotopes are incorporated into tissues preferentially (reviewed by Martínez del Río et al. 2009). Therefore, it is probable that the relationship between feathers and blood for these isotopes is not a simple linear relationship. I support the call of Martínez del Río et al. (2009) for more controlled diet studies using caged birds to help elucidate the relationship between diet and tissue stable isotope signatures for multiple tissues within the same species.

Variances of  $\delta D$  feather values for adult birds were larger than nestling  $\delta D$  feather values at Tallgrass, which supports the hypothesis that adult feathers represent a larger geographic extent due to dispersal between breeding seasons. There was no difference between the variances of  $\delta D$  feather values for adults and nestlings at Homestead. The landscape surrounding Homestead has a greater variety of land cover classes than the landscape around Tallgrass. The similarity between Homestead nestling  $\delta D$  feather variance and adult variances may be attributable to the increase in the types of available foraging habitats and thus a greater variety in the  $\delta D$  signature of Homestead nestling diets.

There were no differences in blood values among nestlings and adults for any of the stable isotopes. This supports the hypothesis that both adults and nestlings have been consuming a diet derived from the same location over the last week (reviewed by Martínez del Río et al. 2009). I did not find any difference between adult and nestling feather  $\delta^{13}C$  or  $\delta^{15}N$  value variances at Tallgrass. However, these differences were only marginally non-significant ( $\delta^{13}C$ :  $P=0.054$ ;  $\delta^{15}N$ :  $P=0.052$ ). During the breeding season,

dickcissel diet consists of about 70% animal and 30% vegetable matter (Gross 1921), eastern meadowlark diet is 74% insects and 36% vegetable matter (Lanyon 1995), and grasshopper sparrows feed mostly on insects (Vickery 1996). It is possible that the diet of adults while growing their feathers on the breeding grounds is sufficiently similar from year to year that feathers grown the preceding breeding season (adult feathers) carry the same carbon ratio as feather grown the current breeding season (nestling feathers). An analysis of stable isotopic signatures of the diet of adults compared with the diet of nestlings would shed light on this.

### *Conclusion*

My study suggests that using stable isotope values from nestlings to establish reference standards for isotopes from a location is a promising alternative to the map approach. Site fidelity estimates for songbird populations can be derived at NPS properties on the Great Plains using this technique. However, songbird populations at any given NPS property are not isolated and management changes and approaches should be considered within a cooperative, region wide community of potential breeding habitat. Direct productivity estimates are a more direct way of monitoring habitat quality at a site, but my method requires considerably less time nest searching and no repeated visits to the nests once found. Managers considering using this technique should take into account all management objectives, including the time and money allotted to nest monitoring and the need for direct demographic measurements before adopting this technique as part of a management plan.

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## Chapter 4 : MULTIMODEL INFERENCE AND ADAPTIVE MANAGEMENT<sup>1</sup>

### *Abstract:*

Ecology is an inherently complex science coping with correlated variables, nonlinear interactions and multiple scales of pattern and process, making it difficult for experiments to result in clear, strong inference. Natural resource managers, policy makers, and stakeholders rely on science to provide timely and accurate management recommendations. However, the time necessary to untangle the complexities of interactions within ecosystems is often far greater than the time available to make management decisions. One method of coping with this problem is multimodel inference. Multimodel inference assesses uncertainty by calculating likelihoods among multiple competing hypotheses, but multimodel inference results are often equivocal. Despite this, there may be pressure for ecologists to provide management recommendations regardless of the strength of their study's inference. We reviewed papers in the Journal of Wildlife Management (JWM) and the journal Conservation Biology (CB) to quantify the prevalence of multimodel inference approaches, the resulting inference (weak versus strong), and how authors dealt with the uncertainty. Thirty-eight percent and 14%, respectively, of articles in the JWM and CB used multimodel inference approaches. Strong inference was rarely observed, with only 7% of JWM and 20% of CB articles resulting in strong inference. We found the majority of

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weak inference papers in both journals (59%) gave specific management recommendations. Model selection uncertainty was ignored in most recommendations for management. We suggest that adaptive management is an ideal method to resolve uncertainty when research results in weak inference.

## INTRODUCTION

Ecology is an inherently complex science studying phenomena characterized by nonlinear interactions that make it difficult to understand basic relationships and responses to management. Most ecological field research is conducted in relatively short, small scale studies (Wiens 1989) which are often inadequate to untangle ecological complexity. Wildlife managers and policy makers, whose decisions affect ecosystems at larger scales in space and time, rely on ecologists to provide management recommendations drawn from these short, small scale studies. To cope with the difficulties associated with drawing conclusions from such studies, ecologists are, with increasing frequency, using alternatives to traditional statistical null hypothesis testing in order to disentangle the underlying trends in complex data (Anderson et al. 2000; Johnson & Omland 2004; Stephens et al. 2007).

Strong inference, where multiple alternative hypotheses are tested with experiments to falsify those hypotheses (Platt 1964), and adaptive inference, an iterative process of investigation that alternates between minimizing Type I and Type II errors at different places in the investigative process (Holling & Allen 2002) have been suggested as approaches appropriate to understanding complex problems. Both approaches pose and test branch points in a tree of logically alternative hypotheses. But strong inference relies on situations where causes can be single and separable and where discrimination between pair-wise alternative hypotheses can be determined experimentally by a simple yes or no answer. As Platt (1964) demonstrates, strong inference is a powerful and rapid way to deal with questions in molecular biology, cell biology and physiology. Strong

inference is less applicable in ecological systems, where causes are not entirely separable (Hilborn & Stearns 1982; Pickett et al. 1994). Frequently, competing hypotheses cannot be distinguished by a single unambiguous test or set of controlled experiments, but only by a suite of tests that accumulate a body of evidence supporting one line of argument and not others. Instead of pitting hypotheses against each other, adaptive inference relies on multiple, competing hypotheses followed by tests that develop a consistency of pattern lending support to a particular line or lines of argument.

Strong inference and adaptive inference are useful, but not appropriate in all situations. One method that is increasing in prevalence within the fields of ecology and conservation is multimodel inference (Guthery et al. 2005; Hobbs & Hilborn 2006). Multimodel inference is a statistical technique where alternative plausible models are assessed given the data, based on relative likelihoods (Anderson et al. 2000). These models are selected *a priori* based on thoughtful, science-based consideration of the problem to be answered and hypotheses about the causal effects behind this problem. These plausible models are then analyzed simultaneously as a set to determine the best approximating model or set of models using information theoretic approaches (Burnham & Anderson 2002). However, model results are often equivocal due to uncertainty in model selection (Guthery et al. 2005), and researchers are left with the resulting weak inference, with multiple models plausible given the data at hand. Researchers are thus faced with the dilemma of providing management recommendations to managers based on weak inference.



When researchers are required to draw conclusions from multiple plausible models, they have at least three alternatives open to them. One method is to average otherwise equivocal results. Model averaging uses model weights to derive more robust model parameters or model estimates (Johnson & Omland 2004). Another alternative is to repeat the experiment and postpone initiating a management regime. However, when management decisions must be made and it is not feasible to repeat the experiment, a third option, adaptive management, is a logical follow up for researchers and managers when drawing conclusions from research with weak multimodel inference. Adaptive management permits management to continue while managers increase their knowledge through monitoring coupled with well designed management experiments. Management is able to continue because in adaptive management uncertainty is acknowledged, management is designed to reduce sources of uncertainty over time, and management actions are designed to be optimal within the current state of uncertainty (Holling 1978; Walters 1986).

The use of adaptive management has been increasing over the last decade (McFadden et al. 2010). Given the changing paradigms in ecological research, that is, the increasing prevalence of multimodel inference, we sought to document the use of multimodel inference in two top management and conservation journals, and the pervasiveness of weak inference resulting from its use. Where weak inference was present in the results from reported field studies, we sought to determine if authors were communicating the uncertainty underlying weak inference to managers, and the type of recommendations that followed from results. Specifically, we evaluated peer-reviewed

papers in two journals to (1) quantify the prevalence of multimodel inference, (2) quantify the prevalence of weak inference, and (3) determine what type of management recommendations authors draw from multimodel inference results. We expected weak inference to be abundant within papers that used multimodel inference, and therefore, given the increasing use of adaptive management, we specifically searched within the management recommendations for the endorsement of an adaptive management approach.

## METHODOLOGY

### *Inference Strength*

We reviewed articles in the 2008 issues of the *Journal of Wildlife Management* (volume 72) and *Conservation Biology* (volume 22). We selected these journals because their target readership includes managers and conservationists, and we wished to understand our objectives within the context of the literature available to these interest groups. Papers were included in our review if (1) data reported were collected from field studies, (2) data were analyzed using multimodel inference (MMI) or statistical null hypothesis testing, and (3) management or conservation predictions or recommendations were drawn from the reported statistical analyses. We excluded commentaries, literature reviews, statistical theory papers, and papers where the objective was to theoretically develop or test a specific type of model (e.g., population growth models) without testing multiple competing statistical hypotheses.

Subsequent analyses were restricted to papers that used MMI as a method of comparing hypotheses (Burnham & Anderson 2002). In the reported results of MMI

papers, we determined the number of models in a confidence set of models based on the minimum cutoff point suggested by Royall (1997) where models in the confidence set are within 10% of the Akaike weight of the top model. Models within the confidence set are considered to be the best supported given the data and the models selected for analysis. It is important to define the confidence set because these models should be taken into consideration when model averaging or discussing model selection results. Where papers did not report Akaike weights, or where Akaike weights were not applicable (i.e., Schwarz's criterion (Schwarz 1978) and deviance information criterion, (DIC) (Spiegelhalter et al. 2002), we designated the confidence set as the set of models within 2  $\Delta$ AIC or  $\Delta$ DIC of the top model (Burnham & Anderson 2002). We categorized papers with only one model supported in all model analyses (a confidence set of one) as strong inference and papers with  $>1$  top model in all model analyses as weak inference. We selected this narrow definition because it most closely approximates the unequivocal conclusion of the null hypothesis test as described by Platt (1964). If some model analyses contained one top model and other analyses within the same paper contain  $>1$  top model, we classified the paper as including both types of inference. Papers that did not provide sufficient information to determine confidence sets were categorized as 'unknown' inference.

### *Management Recommendations*

We categorized each paper's recommendations as non-management, vague, specific, or adaptive. Some papers did not provide explicit management recommendations but predicted how factors beyond local management control (e.g.,

climate change, urban expansion) may change ecosystems or organisms. Vague recommendations listed how the ecosystem needed to be structured or what changes needed to occur without providing managers with explicit actions to implement. Specific recommendations were explicit in what actions managers needed to take and how these actions would directly affect the organism or ecosystem in question. Adaptive recommendations explicitly evoke the implementation of management actions while reducing uncertainty through monitoring in an iterative, learning process.

### *Uncertainty*

To determine if authors acknowledged model selection uncertainty, we searched each paper containing MMI for the term ‘uncertainty’ and recorded the context in which it was used. Authors that did not use the term uncertainty or used the term outside of their model selection results were categorized as not acknowledging uncertainty. If authors mentioned uncertainty as the reason for model-averaging or explicitly stated their model selection as having uncertainty, we categorized them as acknowledging uncertainty. Although authors may have used other means to acknowledge the uncertainty in their model selection, the term ‘uncertainty’ is the most clearly defined and least ambiguous (Regan et al. 2002). Model-averaging is one way in which to deal with uncertainty without having to explicitly use the word ‘uncertain’, so we also quantified how many papers calculated model-averaged estimates.

## RESULTS AND DISCUSSION

### *Inference Strength*

We reviewed 159 articles in the 2008 issues Journal of Wildlife Management (JWM) and 105 articles in Conservation Biology (CB) that met our specific criteria. Thirty-eight percent (61 of 159) and 14% (15 of 105) of articles in JWM and CB, respectively, utilized multimodel inference (Appendix C), with model fit assessed with AIC, second-order pseudo AIC (pAIC), quasi-likelihoods AIC (qAIC), AIC adjusted for small sample sizes (AIC<sub>c</sub>), Bayesian information criterion (BIC), or DIC. The majority of MMI papers contained either weak inference or did not provide sufficient information for us to determine the strength of their inference (Fig. 1).

We encountered a surprising lack of necessary information to properly understand the authors' analysis methods and results, which hindered our ability to interpret the inference strength of many of the reviewed papers. Thirty papers from both journals did not report sufficient information for us to determine what models they considered. Another set of thirty papers reported only a portion of the information needed to interpret their process for model selection. Twelve percent (9 of 76) of all MMI papers reviewed reported no means of assessing model fit (e.g., AIC values or weights). Twenty-eight percent (21 of 76) of all MMI papers reported incomplete multimodel inference results (i.e., only the top models, some sets of models but not others).

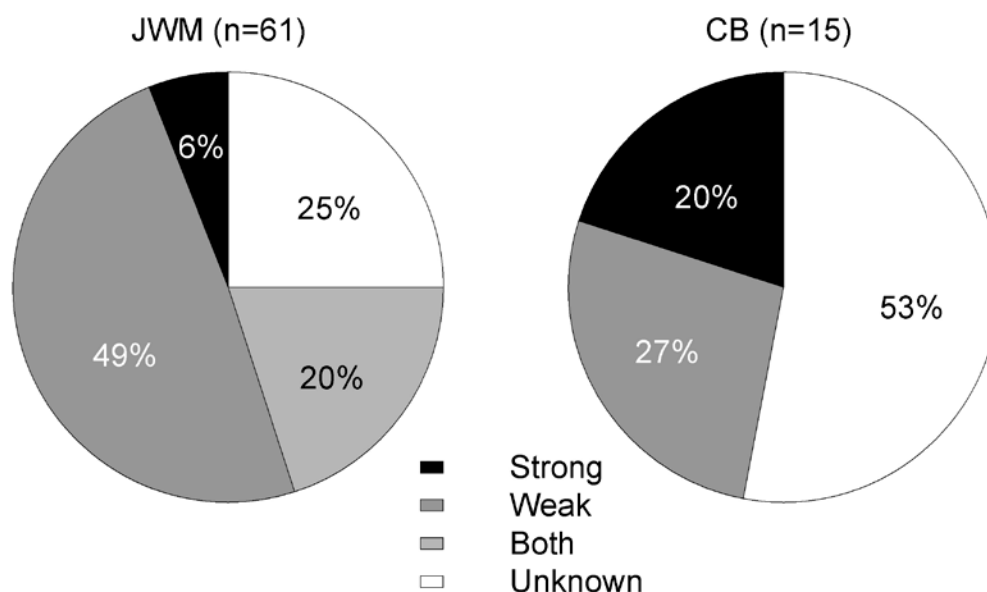


Figure 1. Percentage of multimodel inference papers in the 2008 issues of the Journal of Wildlife Management (JWM) and Conservation Biology (CB) in each multimodel inference strength class. The majority of papers contained weak inference, with >1 model in the confidence set of models, or unknown inference, where authors did not provide sufficient information to determine the confidence set. No CB papers were categorized as 'both' inference strength (papers that contained both strong inference analyses and weak inference analyses).

We encourage editors and reviewers to respond to the call by Anderson et al. (2001b) to provide results of multimodel inference, such as the model set and associated AIC values and model weights. In some cases, the number of models compared or the number of different analyses were too large to reasonably report all models and corresponding information criterion outputs. However, these results could be provided in supplemental material, but no JWM papers and only one CB paper (using an on-line supplement) provided missing information in such a manner. Many journals offer on-line resources for supplemental material, and editors should remind authors of this option, so that they may present their model selection results in full. In some cases, the number of

tested models was too large to report because the authors chose to include all measured variables and almost all possible interactions. It is unlikely that every combination of variables and interactions represents a set of *plausible* models (see Anderson et al. 2001a). Trivial null hypotheses have been criticized in null hypothesis testing (Anderson & Burnham 2002; Robinson & Wainer 2002) and models including variable interactions with no biological basis are no less trivial (Guthery et al. 2005).

### *Management Recommendations and Uncertainty*

Where inference was weak, authors in our sample often provided specific management recommendations (Fig. 2), but the majority of papers failed to acknowledge the resulting uncertainty by using the term ‘uncertainty’ (Table 1). Due to the type of journals we selected, our results exclude journals that do not require authors to propose management recommendations. Therefore, it is possible that management recommendations following weak inference are less pervasive in journals that do not require such recommendations. However, we selected JWM and CB because they are regarded as prominent in the fields of wildlife and habitat management and are read by managers.

When specific management recommendations were suggested without acknowledging uncertainty, authors failed to provide managers and policy makers with complete information on the consequences of management decisions. Further, when authors do not acknowledge the inherent uncertainty in weak inference, they may set unrealistic expectations on the part of those adopting the management recommendations. We may have underestimated the number of papers that implicitly acknowledged the

concept of uncertainty, for we focused on the explicit use of the term ‘uncertainty’. As such, our results may be biased against authors that used an alternate term or implicitly acknowledged uncertainty. None-the-less, we feel this was the best method for taking the authors’ meaning at face-value and mimicking a manager’s perception of the acknowledgment of model selection uncertainty within the article. ‘Uncertainty’ is an established term within adaptive management and is easily recognized by readers. We chose not to attempt to infer authors’ implicit acknowledgement of uncertainty because a measurement of variation in subjective judgment of implicit acknowledgement was beyond the scope of this review (see Regan et al. 2002). Regardless, it is clear that authors, reviewers and editors should be open to the explicit acknowledgement of uncertainty in peer-reviewed papers so that scientists can maintain the transparency that is important to facilitate open communication between scientists and managers.

An important element of effective management of natural resources is the continuing dialog between ecologists and managers (Gunderson et al. 1995; Holling 1978). For managers to effectively use the results of ecological field studies, managers must understand the limitations of the study so that they may properly assess risk in decision making. The appropriate level of risk for any given decision can only be evaluated by the manager and stake-holders. Therefore, ecologists should not presuppose risk is not a factor in the application of their management recommendations. Ecologists can avoid this presupposition by acknowledging any model selection uncertainty.



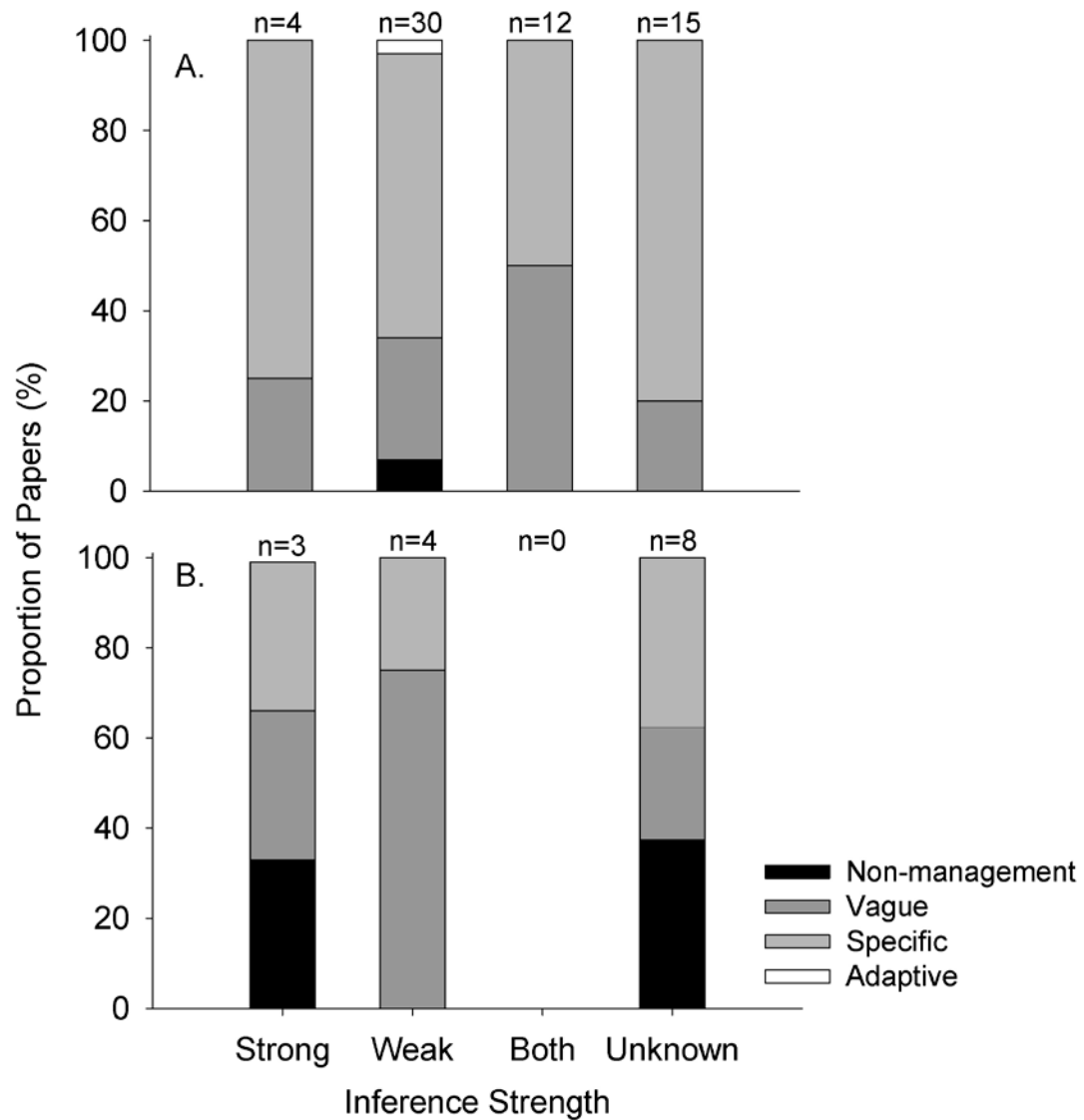


Figure 2. Percentage of papers in each multimodel inference strength class according to the type of recommendation provided in (A) the Journal of Wildlife Management (JWM, n=61) and (B) Conservation Biology (CB, n=15) in 2008. Only 1 paper in either journal provided an adaptive management recommendation. No CB papers were categorized as 'both' inference strength (papers that contained both strong inference analyses and weak inference analyses).

Table 1. The use of the term ‘uncertainty’ in relation to multimodel inference results (number that performed model averaging) in papers in Journal of Wildlife Management (JWM, n=61) and Conservation Biology (CB, n=15) in 2008. The majority of weak inference papers did not use the term ‘uncertainty’, and the majority of these papers did not model average.

Use of term uncertainty	Strong <sup>a</sup>		Weak <sup>b</sup>		Both <sup>c</sup>		Unknown <sup>d</sup>		Total
	JWM	CB	JWM	CB	JWM	CB	JWM	CB	
No mention of uncertainty	3	1	23 (9)	2 (1)	10 (1)	0	14 (4)	7	60
Term used, but unrelated to model selection	1	1	0	0	1	0	1 (1)	1	5
Term used as reason for model averaging	0	0	4 (4)	1 (1)	1 (1)	0	0	0	6
Term used when talking about model selection	0	1	3 (1)	1	0	0	0	0	5
Total	4	3	30	4	12	0	15	8	76

<sup>a</sup> Confidence set = 1 top model.

<sup>b</sup> Confidence set >1 model.

<sup>c</sup> Article contains both strong inference analyses and weak inference analyses.

<sup>d</sup> Not enough information provided to determine confidence set of models.

Burnham and Anderson (2002) advocated the use of quantitative evidence to allow decision-makers to assess what is important; authors should be encouraged to provide such evidence. Only 14% (n=10) of papers in both journals that did not have a strong inference chose to use the term ‘uncertainty’ in relation to their multimodel selection (Table 1). However, 25% of these chose to model average parameters of interest as a way of dealing with multimodel selection uncertainty. To model average, authors must select a confidence set of models across which to average parameter estimates, or they must average across all models. We identified 14 methods by which authors determined their confidence set of models (Table 2). The subjectivity with which

authors selected their confidence set becomes problematic when readers wish to compare the parameters derived from model averaging among studies. Burnham and Anderson (2002) recommended that models within 2  $\Delta$ AIC of the top model be considered as competitive with the top model, models within 2-4  $\Delta$ AIC of the top model be considered as plausible, and models  $>4$   $\Delta$ AIC be considered unlikely. The majority of authors chose to work within this recommendation, but not all authors rationalized their reasoning behind selecting the method that they used for determining the confidence set. The ecological community needs to establish a consistent method for determining confidence sets, and editors can be a part of the solution by restricting the variability allowed among papers.

### *Adaptive Management*

Simply acknowledging uncertainty and model averaging parameters of interest does not fully solve the dilemma faced by managers and policy makers when ecological studies fail to result in strong inference. When strong inference and statistical null hypothesis testing fails or is inapplicable, adaptive inference is a logical alternative course of investigation for understanding complex ecological interactions (Holling & Allen 2002). Multimodel inference is a tool that can be used within adaptive inference. However, adaptive inference does not solve the manager's predicament of how to continue to make management decisions when scientific investigation is weak and uncertain or still in progress. Meta-analyses can also provide better understanding within adaptive inference by coalescing weak inferences from multiple studies to build evidence. But meta-analyses are limited to topics for which there have been many independent

studies. Managers who need to make decisions from one or two weak inference studies are thus at an impasse without adaptive management.

Table 2. Proportion of papers categorized among 14 methods used by authors to select models for their confidence set of models for multimodel inference in the 2008 issues of the Journal of Wildlife Management (JWM) and Conservation Biology (CB). Akaike's information criterion (AIC) was most commonly used, though variations of AIC, Bayesian information criterion, and deviance information criterion were also employed.

Method for Determining Confidence Set	JWM (n=61)	CB (n=15)
Models within 2 $\Delta$ AIC of top model	33 %	20%
No criteria for confidence set reported	28%	47%
Authors used weights comparatively ('best', 'better', or 'more weight')	5%	7%
Lowest AIC value (only one model in confidence set)	7%	13%
Lowest $\Delta$ AIC (no specific AIC value provided)	5%	0
Models within 4 $\Delta$ AIC of top model	5%	0
Listed and discussed evidence ratios	5%	0
Models <2 $\Delta$ AIC of top model are 'competitive', 2-4 $\Delta$ AIC are 'plausible', >4 $\Delta$ AIC are 'unlikely'	3%	0
Models that add up to 95% of total weight	3%	0
Models within 10% of the weight of top model	2%	7%
Models within 10% of the weight of top model or 4 best models	2%	0
Models 0-2 $\Delta$ AIC of top model have 'substantial support', 4-7 $\Delta$ AIC have 'considerably less support', >10 $\Delta$ AIC have essentially no support	2%	0
Models within 10 $\Delta$ AIC of top model	0	7%
Models that add up to 90% of total weight	2%	0

Adaptive management provides a means by which managers can move forward with management despite the uncertainty in weak inference sometimes inherent in statistical methods, including multimodel inference. We suggest that the type of

recommendation must also be tailored to the strength of inference from which it is being drawn. However, only one JWM paper and zero CB papers out of our sample recommended an adaptive approach to management. This one JWM paper was classified as a weak inference paper, but, given the abundant use of MMI and the pervasiveness of weak inference, we feel increased acknowledgement of the utility of adaptive management is needed.

## **CONCLUSION**

Our results demonstrate that weak inference is prevalent in the use of multimodel inference and that authors are failing to acknowledge the resulting uncertainty in their specific management recommendations. Authors and editors should be aware of the importance of acknowledging uncertainty both in explicit terms and through methods such as model averaging, but acknowledgment can only take us so far. We suggest that editors must be open to not requiring specific management recommendations from authors when the research results do not permit strong inference. However, when management recommendations are required, adaptive management is an ideal method for dealing with uncertainty resulting from weak inference.

The strength in adaptive management is that it is a method that can be used despite uncertainty and weak inference and permits the continuation of management in such situations, without spurious certitude. Continued management provides information about the system that reduces uncertainty and improves future management decisions. Working scientists and resource managers can interact transparently and more effectively

to move forward in understanding the ecosystem in question when they are open about the uncertainty, and adaptive management provides a framework in which to do this.

However, merely adding the words ‘adaptive management’ to any set of management recommendations is not enough. Even if their inference is weak, authors can continue to draw conclusions and develop hypotheses from their results. We suggest that authors consider how these hypotheses might be incorporated into and tested using an adaptive management plan. The strength of adaptive management is the ability to take uncertainty about hypotheses or processes and build a management plan that works toward the reduction of uncertainty in the underlying ecological processes and the effects of management actions. In this way, weak inference and the resulting management recommendations can still be useful to managers and policy makers through adaptive management.

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## **Chapter 5 : SUMMARY AND SYNTHESIS**

Due to the extreme declines that have occurred in grassland songbird populations over the last three decades (Sauer et al. 2008), it is imperative that remnant prairies and grasslands be managed and maintained to benefit grassland songbirds (Knopf 1994). National Park Service (NPS) properties on the Great Plains are islands of prairie remaining from a once vast ecosystem, and these islands provide breeding habitat for grassland songbirds. However, little is known about the quality of breeding habitat at these locations and more extensive study into the breeding ecology of these birds has been recognized as necessary (Powell 2000).

Conducting research on grassland songbirds at these locations presents several difficulties. First, these birds are highly mobile, some migrating many thousands of miles every year, and are small, making them difficult to follow from year to year using external tracking techniques (Hobson & Norris 2008). A relatively new method, stable isotope analysis, permits the tracking of birds across years using intrinsic stable isotopic signatures of tissues. These tissues retain the signature of the location where that tissue was generated, and many locations can be differentiated isotopically (Hobson 1999). A second difficulty in research at these sites is the small sizes of some of the properties and corresponding small sample sizes of available study subjects. Ecology is an inherently complex science, complicated by intricate, non-linear relationships. Many ecologists have begun to use multimodel inference in an attempt to unravel these tangled relationships (Guthery et al. 2005; Hobbs & Hilborn 2006). However, model results are

often equivocal due to uncertainty in model selection (Guthery et al. 2005), and ecologists are left with the resulting weak inference.

A method that acknowledges the inherent uncertainty in ecological study results, whether due to small sample sizes, statistical methods, or the complexity of the study subject, and allows management to continue despite uncertainty is needed. Adaptive management is one such method that permits learning through an iterative process that seeks to build a better understanding of the ecosystem and improved, goal-driven management techniques. The results contained within this thesis can and should be incorporated into an adaptive management plan that takes into account the goals and management objectives of each NPS property with respect to grassland songbird conservation.

In chapter 2, I summarized demographic characteristics, including species richness, density, and nest success, of songbird populations and communities at three NPS properties on the Great Plains. My data showed an apparent lack of nesting for many species found during surveys. These results add to the long-term monitoring data currently being collected by the Heartland Inventory and Monitoring Network. When incorporated into an adaptive management plan, both intensive, short-term studies and long-term monitoring data can aid managers in focusing their conservation efforts where they will do the most good.

In chapter 3, I demonstrated that stable isotope analysis offers a promising alternative to extrinsic markers for tracking among year movements of grassland songbirds at NPS properties. Nest searching and monitoring to determine site specific

nest success and thus productivity is time consuming and expensive. Relative fidelity of grassland songbirds may allow comparisons of productivity and survival of breeding populations in respective landscapes. Stable isotope analysis and a new method, using nestlings as known origin birds, to assign origin is a more precise way to monitor site fidelity than the more commonly used method, the map lookup approach.

Due to limitations in sample sizes, I was hindered in my ability to develop strong inference in some of my analyses. To determine how other biologists dealt with similar issues, I conducted a literature review. In chapter 4, I concluded that, when studies result in weak inference and high uncertainty, whether in model selection or any other area of inquiry, authors of scientific papers are failing to acknowledge uncertainty and are providing specific management recommendations. These authors also fail to recommend adaptive management as a logical alternative to making specific management recommendations.

### *Future Research*

The next logical step to incorporate my research results into the management decision process could be the development of a working adaptive management plan that incorporates all the management goals of the individual NPS properties, including educational, historical, and cultural objectives (Gunderson et al. 1995). In addition to providing baseline data for decision-making, my research generated other ecological questions for future research.

A comparable number of grassland obligate species were observed utilizing the grassland at Pipestone, a smaller site, to the habitat at Tallgrass, a large site. However,

few obligates at Pipestone were observed nesting on the property. More research is needed to investigate the non-nesting use of the property by obligates, such as bird movement, foraging habits, and behavior. If the property provides superior foraging habitat but is not attractive as nesting substrate, Pipestone managers could consider managing for insects these birds feed on. It is also important to determine on what other properties these birds are nesting so that conservation within the NPS property's border is linked with conservation across borders.

My stable isotope techniques work best at larger scales across years but are less applicable to short term questions. More information is needed about grassland songbird adult movements during the breeding season at my study sites. Powell and Frasch (2000) found that within season dispersal, of any distance, is advantageous to renesting or multi-brooded songbirds after nest failures in their simulation study. Therefore, managers at these locations should consider within season tracking of adult movement to determine what other properties besides the NPS property these birds are using. In this way, landscape level management, where stakeholders including private land owners and state and federal government work together, can incorporate research, monitoring, and experimentation to prevent the further decline of grassland songbirds and other grassland species.

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## Appendix A: SUPPLEMENTAL AVIAN POINT COUNT SURVEY TABLES AND FIGURES

Table 1. Model selection for bird density (birds/ha) based on radial distance estimation point counts at Tallgrass Prairie National Preserve, Kansas, USA, 2008. See methods section of chapter 2 for a description of models.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
American Crow (n=21)								
Observer	7.41	0.00	0.82	half-normal	0.7664	0.562	450	0.0008 (0.0002-0.0031)
Wind	10.50	3.09	0.18	half-normal	2.2281	0.104		0.0006 (0.0000-0.0100)
Null	254.29	246.88	0.00	uniform	0.281	0.138		0.0003 (0.0002-0.0005)
Barn Swallow (n=22)								
Observer	7.33	0.00	0.96	half-normal	0.4082	0.23	100	0.0304 (0.0139-0.0662)
Wind	13.75	6.42	0.04	half-normal	1.214	0.23		0.0666 (0.0091-0.4869)
Null	197.19	189.86	0.00	uniform	0.455	0.203		0.0309 (0.0130-0.0736)
Blue Jay (n=16)								
Wind	16.00	0.00	1.00	half-normal	2.3034	0.721	350	0.0008 (0.0000-0.0164)
Null	187.30	171.30	0.00	neg. exp. <sup>h</sup>	0.6933	0.995		0.0012 (0.0003-0.0042)
Observer	192.11	176.11	0.00	half-normal	0.4892	0.722		0.0008 (0.0003-0.0020)
Brown-headed Cowbird (n=387)								
Wind	3968.29	0.00	0.99	hazard	0.098	0.243	300	0.1299 (0.1072-0.1574)
Null	3978.43	10.14	0.01	hazard	0.121	0.112		0.1116 (0.0881-0.1415)
Observer	3983.38	15.09	0.00	hazard	0.096	0.001		0.0970 (0.0804-0.1170)
Common Nighthawk (n=46)								
Observer	486.65	0.00	0.95	half-normal	0.264	0.163	375	0.0162 (0.0097-0.0271)
Wind	492.51	5.86	0.05	half-normal	0.466	0.822		0.0177 (0.0073-0.0429)
Null	502.11	15.46	0.00	hazard	0.334	0.868		0.0171 (0.0090-0.0325)



Table 1. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
Dickcissel (n=943)								
Null	9261.81	0.00	1.00	hazard	0.052	0.001	450	0.4332 (0.3914-0.4795)
Observer	9280.48	18.67	0.00	hazard	0.048	0		0.3693 (0.3363-0.4056)
Wind	9286.56	24.75	0.00	hazard	0.048	0		0.3675 (0.3346-0.4035)
Eastern Meadowlark (n=889)								
Observer	9249.14	0.00	1.00	hazard	0.066	0.003	400	0.2599 (0.2282-0.2960)
Wind	9313.48	64.34	0.00	hazard	0.066	0.053		0.2660 (0.2337-0.3027)
Null	9338.47	89.33	0.00	hazard	0.072	0.008		0.2493 (0.2163-0.2872)
Field Sparrow (n=22)								
Wind	235.12	0.00	0.83	half-normal	0.64	0.64	300	0.0100 (0.0031-0.0325)
Null	238.30	3.18	0.17	half-normal	0.468	0.468		0.0087 (0.0036-0.0210)
Grasshopper Sparrow (n=538)								
Observer	5111.37	0.00	0.98	half-normal	0.069	0	250	0.3823 (0.3342-0.4373)
Wind	5120.66	9.29	0.01	half-normal	0.068	0		0.3779 (0.3306-0.4320)
Null	5120.75	9.38	0.01	hazard	0.244	0		0.3414 (0.2129-0.5474)
Killdeer (n=21)								
Wind	14.00	0.00	1.00	half-normal	0.341	0.341	150	0.0076 (0.0039-0.0145)
Null	201.61	187.61	0.00	uniform	0.393	0.393		0.0147 (0.0069-0.0313)
Mourning Dove (n=51)								
Wind	13.91	0.00	1.00	half-normal	0.936	0.069	500	0.0060 (0.0012-0.0295)
Observer	627.58	613.67	0.00	half-normal	0.268	0.511		0.0032 (0.0019-0.0054)
Null	632.61	618.70	0.00	hazard	2.228	0.873		0.0157 (0.0011-0.2309)
Northern Bobwhite (n=93)								
Observer	1005.20	0.00	1.00	hazard	0.162	0.103	400	0.0204 (0.0148-0.0279)
Null	1040.50	35.30	0.00	hazard	0.227	0.408		0.0186 (0.0119-0.0290)
Wind	1058.14	52.94	0.00	hazard	0.148	0.156		0.0165 (0.0124-0.0220)

Table 1. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Northern Rough-winged Swallow (n=27)								
Wind	7.04	0.00	1.00	half-normal	1.8771	0.134	75	0.0473 (0.0038-0.5928)
Null	218.49	211.45	0.00	hazard	0.3525	0.126		0.0328 (0.0167-0.0644)
Red-winged Blackbird (n=69)								
Observer	757.98	0.00	0.69	hazard	0.1952	0.552	350	0.0097 (0.0067-0.0142)
Null	759.58	1.60	0.31	hazard	0.3305	0.703		0.0095 (0.0050-0.0181)
Wind	767.26	9.28	0.01	hazard	0.196	0.775		0.0105 (0.0072-0.0155)
Upland Sandpiper (n=197)								
Wind	12.44	0.00	1.00	half-normal	0.14	0.332	500	0.0182 (0.0138-0.0240)
Observer	2249.80	2237.36	0.00	hazard	0.143	0.029		0.0600 (0.0454-0.0793)
Null	2313.75	2301.31	0.00	half-normal	0.151	0.498		0.0500 (0.0373-0.0671)
Western Meadowlark (n=21)								
Wind	13.71	0.00	1.00	half-normal	1.659	0.421	180	0.0020 (0.0002-0.0241)
Null	125.49	111.78	0.00	neg. exp. <sup>h</sup>	0.793	0.838		0.0032 (0.0006-0.0157)
Observer	128.64	114.93	0.00	half-normal	none	0.896		0.0020 (0.0000-1.3467)

<sup>a</sup> AICc = Akaike's Information Criterion adjusted for small sample sizes<sup>b</sup>  $\Delta$ AICc = relative adjustment of AICc<sup>c</sup>  $w_i$  = Akaike weights<sup>d</sup> Key function = model function shape selected as the best fit<sup>e</sup> %CV = percent coefficient of variation<sup>f</sup> GOF K-S p = p-value for Kolmogorov Smirnov goodness-of-fit test<sup>g</sup>  $\rho$  = effective radius in meters<sup>h</sup> Negative Exponential

Table 2. Model selection for bird density (birds/ha) based on radial distance estimation point counts at Pipestone National Monument, Minnesota, USA, 2008. See methods section of chapter 2 for a description of models.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
American Crow (n=117)								
Audio/Visual	4.11	0.00	1.00	half-normal	11.8%	0.000	500	0.0010 (0.0008-0.0012)
Null	1386.48	1382.37	0.00	uniform	11.5%	0.000		0.0009 (0.0007-0.0012)
American Goldfinch (n=65)								
Null	634.18	0.00	1.00	hazard	27.1%	0.658	500	0.0492 (0.0291-0.0831)
Audio/Visual	654.17	19.99	0.00	half-normal	22.9%	0.000		0.0326 (0.0209-0.0508)
Observer	670.28	36.10	0.00	hazard	22.6%	0.000		0.0185 (0.0119-0.0287)
Wind	682.09	47.91	0.00	hazard	22.9%	0.000		0.0185 (0.0119-0.0289)
American Robin (n=86)								
Audio/Visual	924.76	0.00	1.00	half-normal	19.5%	0.000	500	0.0198 (0.0135-0.0290)
Null	980.74	55.98	0.00	hazard	30.9%	0.633		0.0304 (0.0167-0.0552)
Observer	1015.20	90.44	0.00	half-normal	23.3%	0.000		0.0130 (0.0083-0.0204)
Wind	1037.46	112.70	0.00	hazard	18.7%	0.000		0.0059 (0.0041-0.0085)
Barn Swallow (n=27)								
Null	264.00	0.00	0.50	uniform	142.2%	0.000	200	0.0013 (0.0002-0.0106)
Wind	266.16	2.16	0.17	half-normal	144.9%	0.000		0.0013 (0.0002-0.0109)
Audio/Visual	266.16	2.16	0.17	half-normal	144.9%	0.000		0.0013 (0.0002-0.0109)
Observer	266.16	2.16	0.17	half-normal	144.9%	0.000		0.0013 (0.0002-0.0109)
Blue Jay (n=18)								
Audio/Visual	4.80	0.00	0.96	half-normal	57.8%	0.002	500	0.0006 (0.0002-0.0017)
Wind	11.08	6.28	0.04	half-normal	168.3%	0.002		0.0005 (0.0000-0.0057)
Null	219.38	214.58	0.00	uniform	28.3%	0.002		0.0001 (0.0001-0.0002)
Observer	221.63	216.83	0.00	half-normal	39.8%	0.002		0.0001 (0.0001-0.0003)

Table 2. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Bobolink (n=271)								
Audio/Visual	2811.56	0.00	1.00	half-normal	15.8%	0.001	400	0.0828 (0.0608-0.1128)
Null	2930.26	118.70	0.00	hazard	18.2%	0.212		0.0905 (0.0636-0.1290)
Wind	2942.18	130.62	0.00	hazard	15.8%	0.000		0.0571 (0.0419-0.0777)
Observer	2958.21	146.65	0.00	hazard	15.5%	0.000		0.0513 (0.0379-0.0695)
Brown-headed Cowbird (n=155)								
Observer	6.16	0.00	1.00	half-normal	17.0%	0.021	500	0.0214 (0.0154-0.0298)
Audio/Visual	1701.02	1694.86	0.00	half-normal	16.4%	0.000		0.0296 (0.0215-0.0408)
Null	1704.27	1698.11	0.00	hazard	20.6%	0.204		0.0578 (0.0387-0.0863)
Wind	1742.70	1736.54	0.00	hazard	16.5%	0.000		0.0222 (0.0161-0.0307)
Clay-colored Sparrow (n=124)								
Audio/Visual	1254.99	0.00	1.00	half-normal	14.5%	0.010	300	0.0415 (0.0313-0.0552)
Null	1303.53	48.54	0.00	hazard	27.8%	0.070		0.0731 (0.0426-0.1252)
Wind	1313.68	58.69	0.00	half-normal	17.5%	0.011		0.0288 (0.0204-0.0405)
Observer	1316.64	61.65	0.00	half-normal	13.1%	0.018		0.0251 (0.0194-0.0325)
Common Grackle (n=177)								
Wind	1946.24	0.00	1.00	half-normal	24.0%	0.002	340	0.0260 (0.0164-0.0414)
Null	1963.31	17.07	0.00	uniform	23.2%	0.081		0.0265 (0.0169-0.0415)
Observer	1988.42	42.18	0.00	hazard	22.9%	0.012		0.0208 (0.0133-0.0324)
Audio/Visual	1989.84	43.60	0.00	hazard	22.9%	0.014		0.0203 (0.0130-0.0316)
Common Yellowthroat (n=81)								
Observer	6.31	0.00	1.00	half-normal	23.8%	0.096	350	0.0108 (0.0068-0.0173)
Audio/Visual	839.03	832.72	0.00	half-normal	19.4%	0.018		0.0297 (0.0204-0.0435)
Null	890.60	884.29	0.00	neg. exp. <sup>h</sup>	19.1%	0.044		0.0297 (0.0204-0.0432)
Wind	900.17	893.86	0.00	hazard	16.1%	0.486		0.0130 (0.0095-0.0178)

Table 2. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Dickcissel (n=122)								
Observer	6.20	0.00	1.00	half-normal	19.3%	0.005	500	0.0027 (0.0019-0.0039)
Audio/Visual	1473.08	1466.88	0.00	half-normal	14.7%	0.005		0.0039 (0.0029-0.0052)
Wind	1495.67	1489.47	0.00	half-normal	11.1%	0.006		0.0030 (0.0024-0.0037)
Null	1501.35	1495.15	0.00	neg. exp. <sup>h</sup>	19.6%	0.040		0.0047 (0.0032-0.0069)
Eastern Kingbird (n=94)								
Observer	6.27	0.00	0.97	half-normal	14.8%	0.002	400	0.0114 (0.0085-0.0153)
Wind	12.97	6.70	0.03	half-normal	26.4%	0.002		0.0174 (0.0104-0.0291)
Audio/Visual	965.83	959.56	0.00	half-normal	15.7%	0.400		0.0245 (0.0180-0.0332)
Null	1003.26	996.99	0.00	hazard	18.6%	0.860		0.0192 (0.0134-0.0277)
Field Sparrow (n=34)								
Audio/Visual	399.17	0.00	0.85	half-normal	40.5%	0.420	500	0.0030 (0.0014-0.0065)
Observer	403.56	4.39	0.09	half-normal	26.6%	0.165		0.0019 (0.0011-0.0031)
Null	405.71	6.54	0.03	uniform	24.7%	0.197		0.0015 (0.0009-0.0024)
Wind	406.02	6.85	0.03	half-normal	50.3%	0.600		0.0024 (0.0009-0.0062)
Gray Catbird (n=26)								
Wind	13.00	0.00	1.00	half-normal	36.2%	0.931	200	0.0056 (0.0028-0.0113)
Audio/Visual	267.59	254.59	0.00	half-normal	29.7%	0.877		0.0049 (0.0028-0.0087)
Null	273.20	260.20	0.00	uniform	25.4%	0.750		0.0037 (0.0023-0.0061)
Observer	274.68	261.68	0.00	half-normal	28.5%	0.593		0.0041 (0.0024-0.0071)
Mourning Dove (n=29)								
Observer	4.46	0.00	0.48	half-normal	44.5%	0.000	500	0.0027 (0.0011-0.0063)
Audio/Visual	4.46	0.00	0.48	half-normal	35.6%	0.000		0.0045 (0.0023-0.0090)
Wind	9.67	5.21	0.04	half-normal	26.3%	0.000		0.0004 (0.0002-0.0007)
Null	357.26	352.80	0.00	hazard	120.4%	0.000		0.0033 (0.0005-0.0233)

Table 2. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Northern Flicker (n=58)								
Observer	6.44	0.00	1.00	half-normal	19.0%	0.086	500	0.0017 (0.0012-0.0024)
Audio/Visual	670.68	664.24	0.00	half-normal	23.5%	0.033		0.0064 (0.0041-0.0101)
Null	715.12	708.68	0.00	uniform	26.6%	0.367		0.0066 (0.0039-0.0111)
Wind	727.87	721.43	0.00	hazard	21.8%	0.284		0.0043 (0.0028-0.0066)
Red-winged Blackbird (n=432)								
Audio/Visual	4901.85	0.00	1.00	hazard	15.7%	0.002	500	0.0409 (0.0302-0.0556)
Null	4980.85	79.00	0.00	half-normal	18.8%	0.002		0.0429 (0.0298-0.0617)
Wind	5001.83	99.98	0.00	hazard	15.6%	0.001		0.0395 (0.0291-0.0536)
Observer	5016.47	114.62	0.00	hazard	15.5%	0.000		0.0449 (0.0331-0.0607)
Ring-necked Pheasant (n=372)								
Observer	6.07	0.00	0.99	half-normal	9.9%	0.000	500	0.0088 (0.0072-0.0106)
Wind	16.40	10.33	0.01	half-normal	12.7%	0.000		0.0103 (0.0081-0.0132)
Audio/Visual	4504.35	4498.28	0.00	half-normal	11.3%	0.000		0.0127 (0.0102-0.0159)
Null	4543.05	4536.98	0.00	uniform	11.2%	0.000		0.0123 (0.0099-0.0153)
Savannah Sparrow (n=31)								
Audio/Visual	293.22	0.00	1.00	half-normal	28.8%	0.574	200	0.0149 (0.0085-0.0261)
Null	315.35	22.13	0.00	hazard	68.8%	0.805		0.0205 (0.0058-0.0727)
Observer	319.92	26.70	0.00	half-normal	26.4%	0.074		0.0069 (0.0041-0.0115)
Wind	328.53	35.31	0.00	half-normal	31.3%	0.078		0.0074 (0.0040-0.0136)
Sedge Wren (n=95)								
Audio/Visual	1078.06	0.00	1.00	hazard	16.5%	0.072	400	0.0089 (0.0064-0.0122)
Null	1111.26	33.20	0.00	neg. exp. <sup>h</sup>	18.6%	0.047		0.0149 (0.0104-0.0215)
Observer	1118.18	40.12	0.00	hazard	13.6%	0.017		0.0065 (0.0050-0.0085)

Table 2. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Song Sparrow (n=75)								
Audio/Visual	723.71	0.00	1.00	hazard	19.9%	0.138	300	0.0452 (0.0307-0.0665)
Null	776.78	53.07	0.00	hazard	33.1%	0.540		0.0507 (0.0268-0.0959)
Observer	805.46	81.75	0.00	hazard	17.9%	0.000		0.0131 (0.0093-0.0186)
Wind	809.13	85.42	0.00	half-normal	94.7%	0.000		0.0195 (0.0040-0.0963)
Western Meadowlark (n=213)								
Audio/Visual	2506.61	0.00	1.00	half-normal	14.6%	0.034	500	0.0117 (0.0088-0.0155)
Observer	2568.00	61.39	0.00	hazard	11.7%	0.259		0.0066 (0.0053-0.0083)
Null	2608.65	102.04	0.00	hazard	18.5%	0.086		0.0064 (0.0044-0.0091)
Wind	2613.93	107.32	0.00	hazard	579.2%	0.255		0.0063 (0.0002-0.2594)

<sup>a</sup> AICc = Akaike's Information Criterion adjusted for small sample sizes<sup>b</sup>  $\Delta$ AICc = relative adjustment of AICc<sup>c</sup>  $w_i$  = Akaike weights<sup>d</sup> Key function = model function shape selected as the best fit<sup>e</sup> %CV = percent coefficient of variation<sup>f</sup> GOF K-S p = p-value for Kolmogorov Smirnov goodness-of-fit test<sup>g</sup>  $\rho$  = effective radius in meters<sup>h</sup> Negative Exponential

Table 3. Model selection for bird density (birds/ha) based on radial distance estimation point counts at Homestead National Monument, Nebraska, USA, 2008. See methods section of chapter 2 for a description of models.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
American Goldfinch (n=121)								
Wind	1097.52	0.00	0.92	half-normal	71.0%	0.316	159	0.1780 (0.0503-0.6303)
Null	1103.10	5.58	0.06	uniform	19.7%	0.415		0.1787 (0.1218-0.2624)
Audio/Visual	1105.01	7.49	0.02	hazard	18.8%	0.544		0.1339 (0.0928-0.1933)
Observer	1109.08	11.56	0.00	hazard	17.0%	0.074		0.1102 (0.0791-0.1535)
American Robin (n=38)								
Wind	14.71	0.00	1.00	half-normal	58.4%	0.662	231	0.0526 (0.0175-0.1575)
Null	373.80	359.09	0.00	hazard	29.4%	0.999		0.0316 (0.0178-0.0561)
Audio/Visual	376.33	361.62	0.00	hazard	23.1%	0.987		0.0287 (0.0183-0.0452)
Observer	377.66	362.95	0.00	hazard	23.2%	0.152		0.0391 (0.0248-0.0615)
Baltimore Oriole (n=63)								
Audio/Visual	592.99	0.00	0.79	hazard	24.8%	0.644	202	0.0474 (0.0293-0.0767)
Null	596.17	3.18	0.16	hazard	26.4%	0.841		0.0473 (0.0284-0.0787)
Observer	598.85	5.86	0.04	hazard	24.8%	0.656		0.0435 (0.0269-0.0703)
Wind	602.42	9.43	0.01	hazard	26.2%	0.776		0.0483 (0.0291-0.0801)
Brown-headed Cowbird (n=181)								
Audio/Visual	4.07	0.00	1.00	half-normal	45.8%	0.399	157	0.1111 (0.0470-0.2624)
Observer	1732.47	1728.40	0.00	half-normal	15.4%	0.901		0.1355 (0.1002-0.1833)
Wind	1744.55	1740.48	0.00	hazard	15.5%	0.775		0.1054 (0.0779-0.1426)
Null	1755.00	1750.93	0.00	hazard	17.7%	0.800		0.1065 (0.0754-0.1506)
Brown Thrasher (n=45)								
Null	427.90	0.00	0.64	hazard	30.8%	0.990	147	0.0359 (0.0198-0.0652)
Observer	430.32	2.42	0.19	hazard	24.3%	0.887		0.0395 (0.0246-0.0633)
Audio/Visual	430.62	2.72	0.16	hazard	24.3%	0.673		0.0416 (0.0260-0.0668)
Wind	439.56	11.66	0.00	half-normal	30.5%	0.276		0.0424 (0.0234-0.0766)



Table 3. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
Common Yellowthroat (n=193)								
Audio/Visual	1740.66	0.00	1.00	half-normal	11.2%	0.020	152	0.2334 (0.1875-0.2906)
Observer	1752.35	11.69	0.00	half-normal	11.1%	0.020		0.2217 (0.1784-0.2755)
Null	1754.94	14.28	0.00	hazard	12.1%	0.254		0.1613 (0.1274-0.2043)
Wind	1766.32	25.66	0.00	half-normal	11.2%	0.020		0.2182 (0.1751-0.2717)
Dickcissel (n=386)								
Wind	14.30	0.00	1.00	half-normal	7.3%	0.031	179	0.3134 (0.2717-0.3614)
Null	3714.12	3699.82	0.00	half-normal	10.3%	0.761		0.4501 (0.3677-0.5509)
Observer	3717.83	3703.53	0.00	half-normal	7.1%	0.080		0.3164 (0.2754-0.3635)
Audio/Visual	3723.28	3708.98	0.00	half-normal	7.0%	0.062		0.3089 (0.2693-0.3544)
Eastern Kingbird (n=43)								
Wind	11.62	0.00	1.00	half-normal	40.1%	0.571	178	0.0291 (0.0135-0.0625)
Observer	428.94	417.32	0.00	half-normal	35.3%	0.680		0.0244 (0.0124-0.0479)
Null	433.32	421.70	0.00	uniform	32.4%	0.753		0.0215 (0.0115-0.0401)
Audio/Visual	433.62	422.00	0.00	half-normal	31.6%	0.826		0.0193 (0.0105-0.0355)
Eastern Meadowlark (n=19)								
Wind	10.86	0.00	1.00	half-normal	47.0%	0.470	239	0.0059 (0.0024-0.0145)
Observer	203.92	193.06	0.00	half-normal	42.7%	0.427		0.0045 (0.0020-0.0100)
Audio/Visual	204.55	193.69	0.00	half-normal	41.1%	0.411		0.0043 (0.0020-0.0093)
Null	205.66	194.80	0.00	neg. exp. <sup>h</sup>	55.1%	0.551		0.0072 (0.0026-0.0204)
Eastern Wood-pewee (n=16)								
Wind	16.00	0.00	1.00	half-normal	73.0%	0.730	133	0.0197 (0.0050-0.0778)
Audio/Visual	148.76	132.76	0.00	half-normal	47.0%	0.470		0.0234 (0.0096-0.0574)
Observer	151.44	135.44	0.00	half-normal	55.5%	0.555		0.0242 (0.0084-0.0693)
Null	152.94	136.94	0.00	neg. exp. <sup>h</sup>	52.0%	0.520		0.0332 (0.0124-0.0891)

Table 3. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
Gray Catbird (n=118)								
Null	1080.54	0.00	0.78	hazard	17.6%	0.731	222	0.1420 (0.1007-0.2002)
Observer	1085.22	4.68	0.07	hazard	15.7%	0.093		0.1055 (0.0777-0.1433)
Audio/Visual	1085.22	4.68	0.07	hazard	15.7%	0.095		0.1057 (0.0778-0.1435)
Wind	1085.27	4.73	0.07	hazard	16.2%	0.590		0.1273 (0.0927-0.1747)
Mourning Dove (n=24)								
Audio/Visual	4.57	0.00	1.00	half-normal	39.0%	0.630	180	0.0062 (0.0029-0.0129)
Wind	16.94	12.37	0.00	half-normal	none	0.698		0.0105 (0.0000-6.1612)
Observer	233.00	228.43	0.00	half-normal	52.1%	0.599		0.0141 (0.0053-0.0374)
Null	247.83	243.26	0.00	neg. exp. <sup>h</sup>	55.9%	0.859		0.0086 (0.0030-0.0245)
Red-winged Blackbird (n=418)								
Observer	4108.51	0.00	0.72	half-normal	11.5%	0.003	214	0.3399 (0.2714-0.4256)
Null	4110.37	1.86	0.28	neg. exp. <sup>h</sup>	12.5%	0.247		0.8105 (0.6350-1.0346)
Wind	4131.43	22.92	0.00	hazard	11.4%	0.004		0.3327 (0.2662-0.4157)
Ring-necked Pheasant (n=43)								
Observer	439.15	0.00	0.52	hazard	25.8%	0.634	185	0.0407 (0.0247-0.0672)
Audio/Visual	439.60	0.45	0.42	hazard	25.4%	0.557		0.0278 (0.0170-0.0456)
Null	443.32	4.17	0.06	neg. exp. <sup>h</sup>	30.6%	0.697		0.0378 (0.0208-0.0684)
Wind	453.97	14.82	0.00	half-normal	44.4%	0.781		0.0205 (0.0088-0.0481)

Table 3. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Song Sparrow (n=17)								
Wind	20.40	0.00	1.00	half-normal	260.9%	0.248	99	0.0441 (0.0019-1.0277)
Observer	150.65	130.25	0.00	half-normal	37.1%	0.925		0.0311 (0.0150-0.0642)
Null	151.98	131.58	0.00	neg. exp. <sup>h</sup>	49.8%	0.837		0.0542 (0.0206-0.1423)
Audio/Visual	154.67	134.27	0.00	half-normal	32.8%	0.893		0.0252 (0.0133-0.0478)

<sup>a</sup> AICc = Akaike's Information Criterion adjusted for small sample sizes

<sup>b</sup>  $\Delta$ AICc = relative adjustment of AICc

<sup>c</sup>  $w_i$  = Akaike weights

<sup>d</sup> Key function = model function shape selected as the best fit

<sup>e</sup> %CV = percent coefficient of variation

<sup>f</sup> GOF K-S p = p-value for Kolmogorov Smirnov goodness-of-fit test

<sup>g</sup>  $\rho$  = effective radius in meters

<sup>h</sup> Negative Exponential

Table 4. Model selection for bird density (birds/ha) based on radial distance estimation point counts at Tallgrass Prairie National Preserve, Kansas, USA, 2009. See methods section of chapter 2 for a description of models.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
American Crow (n=33)								
Observer	4.40	0.00	0.50	half-normal	20.3%	0.000	500	0.0004 (0.0003-0.0006)
Audio/Visual	4.40	0.00	0.50	half-normal	19.9%	0.000		0.0004 (0.0003-0.0006)
Wind	12.22	7.82	0.01	half-normal	20.3%	0.000		0.0004 (0.0003-0.0006)
Null	380.45	376.05	0.00	uniform	19.8%	0.000		0.0004 (0.0003-0.0006)
Barn Swallow (n=25)								
Wind	13.16	0.00	1.00	half-normal	118.8%	0.780	122	0.0304 (0.0043-0.2123)
Audio/Visual	222.13	208.97	0.00	hazard	32.2%	0.992		0.0171 (0.0092-0.0318)
Null	222.13	208.97	0.00	hazard	32.2%	0.992		0.0171 (0.0092-0.0318)
Observer	224.83	211.67	0.00	hazard	31.6%	0.994		0.0171 (0.0092-0.0318)
Brown-headed Cowbird (n=448)								
Null	4664.12	0.00	1.00	half-normal	12.9%	0.072	400	0.1695 (0.1317-0.2180)
Audio/Visual	4680.73	16.61	0.00	half-normal	11.8%	0.000		0.1257 (0.0998-0.1582)
Observer	4688.70	24.58	0.00	hazard	11.7%	0.000		0.0946 (0.0752-0.1190)
Wind	4691.69	27.57	0.00	half-normal	11.8%	0.000		0.1245 (0.0989-0.1568)
Common Nighthawk (n=64)								
Observer	712.45	0.00	0.43	hazard	98.0%	0.857	295	0.0093 (0.0063-0.0137)
Null	712.67	0.22	0.39	hazard	33.4%	0.843		0.0103 (0.0054-0.0196)
Audio/Visual	714.29	1.84	0.17	hazard	19.9%	0.803		0.0102 (0.0069-0.0150)
Wind	719.43	6.98	0.01	half-normal	21.5%	0.375		0.0087 (0.0057-0.0132)
Dickcissel (n=780)								
Observer	8214.74	0.00	0.95	half-normal	6.3%	0.002	297	0.1902 (0.1690-0.2141)
Audio/Visual	8220.78	6.04	0.05	half-normal	6.0%	0.018		0.1953 (0.1726-0.2209)
Wind	8291.17	76.43	0.00	half-normal	5.9%	0.044		0.1749 (0.1557-0.1965)
Null	8292.85	78.11	0.00	hazard	.27.9	0.285		0.1712 (0.1000-0.2932)

Table 4. continued.

Model	AICc <sup>a</sup>	ΔAICc <sup>b</sup>	w <sub>i</sub> <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	ρ <sup>g</sup>	Density (95% CI)
Eastern Meadowlark (n=724)								
Audio/Visual	7999.71	0.00	1.00	half-normal	7.0%	0.000	359	0.0916 (0.0798-0.1050)
Observer	8055.68	55.97	0.00	half-normal	6.7%	0.000		0.0855 (0.0749-0.0976)
Null	8062.74	63.03	0.00	hazard	8.6%	0.031		0.0857 (0.0723-0.1015)
Wind	8065.90	66.19	0.00	half-normal	6.7%	0.000		0.0852 (0.0746-0.0972)
Grasshopper Sparrow (n=356)								
Observer	2914.66	0.00	1.00	hazard	8.7%	0.000	85	0.3355 (0.2829-0.3979)
Audio/Visual	2926.76	12.10	0.00	hazard	8.5%	0.000		0.2983 (0.2524-0.3526)
Wind	2930.26	15.60	0.00	hazard	8.5%	0.000		0.2990 (0.2529-0.3535)
Null	2934.61	19.95	0.00	hazard	29.3%	0.000		0.2935 (0.1668-0.5162)
Henslow's Sparrow (n=59)								
Wind	13.62	0.00	1.00	half-normal	49.8%	0.018	73	0.1775 (0.0694-0.4538)
Null	444.85	431.23	0.00	hazard	62.0%	0.022		0.1176 (0.0377-0.2669)
Audio/Visual	445.23	431.61	0.00	hazard	20.3%	0.040		0.1118 (0.0753-0.1660)
Observer	445.23	431.61	0.00	hazard	20.3%	0.041		0.1115 (0.0751-0.1657)
Mourning Dove (n=74)								
Audio/Visual	843.36	0.00	1.00	hazard	25.6%	0.126	500	0.0043 (0.0026-0.0071)
Wind	892.48	49.12	0.00	half-normal	none	0.552		0.0045 (0.0000-1.4524)
Null	906.55	63.19	0.00	uniform	17.1%	0.130		0.0023 (0.0017-0.0032)
Observer	907.84	64.48	0.00	half-normal	17.3%	0.269		0.0023 (0.0016-0.0032)
Northern Bobwhite (n=119)								
Null	1384.33	0.00	0.52	hazard	9.6%	0.005	450	0.0027 (0.0022-0.0033)
Observer	1384.96	0.63	0.38	hazard	9.4%	0.007		0.0027 (0.0023-0.0033)
Audio/Visual	1389.10	4.77	0.05	hazard	9.2%	0.025		0.0025 (0.0021-0.0030)
Wind	1389.16	4.83	0.05	hazard	9.5%	0.025		0.0028 (0.0023-0.0033)

Table 4. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Northern Rough-winged Swallow (n=56)								
Null	504.27	0.00	0.86	uniform	30.7%	0.415	110	0.0622 (0.0345-0.1122)
Wind	509.99	5.72	0.05	half-normal	31.8%	0.107		0.0544 (0.0295-0.1004)
Audio/Visual	510.26	5.99	0.04	hazard	28.3%	0.349		0.0530 (0.0307-0.0915)
Observer	510.26	5.99	0.04	hazard	28.2%	0.459		0.0525 (0.0305-0.0905)
Red-winged Blackbird (n=154)								
Audio/Visual	1780.53	0.00	0.67	hazard	15.7%	0.523	500	0.0075 (0.0055-0.0101)
Null	1783.16	2.63	0.18	hazard	16.1%	0.471		0.0078 (0.0057-0.0106)
Observer	1783.63	3.10	0.14	half-normal	15.9%	0.233		0.0116 (0.0085-0.0159)
Wind	1788.13	7.60	0.01	hazard	15.8%	0.312		0.0072 (0.0053-0.0098)
Upland Sandpiper (n=173)								
Observer	2093.43	0.00	0.92	hazard	13.9%	0.001	500	0.0051 (0.0039-0.0067)
Audio/Visual	2098.21	4.78	0.08	hazard	14.0%	0.064		0.0045 (0.0034-0.0059)
Null	2115.52	22.09	0.00	neg. exp. <sup>h</sup>	42.4%	0.052		0.0086 (0.0039-0.0192)
Wind	2122.00	28.57	0.00	half-normal	14.3%	0.533		0.0066 (0.0050-0.0087)

<sup>a</sup> AICc = Akaike's Information Criterion adjusted for small sample sizes<sup>b</sup>  $\Delta$ AICc = relative adjustment of AICc<sup>c</sup>  $w_i$  = Akaike weights<sup>d</sup> Key function = model function shape selected as the best fit<sup>e</sup> %CV = percent coefficient of variation<sup>f</sup> GOF K-S p = p-value for Kolmogorov Smirnov goodness-of-fit test<sup>g</sup>  $\rho$  = effective radius in meters<sup>h</sup> Negative Exponential

Table 5. Model selection for bird density (birds/ha) based on radial distance estimation point counts at Pipestone National Monument, Minnesota, USA, 2009. See methods section of chapter 2 for a description of models.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
American Crow (n=72)								
Null	849.10	0.00	0.62	hazard	27.0%	0.001	600	0.0014 (0.0008-0.0024)
Observer	851.49	2.39	0.19	hazard	26.0%	0.002		0.0014 (0.0008-0.0023)
Audio/Visual	851.53	2.43	0.19	hazard	26.0%	0.002		0.0014 (0.0008-0.0023)
Wind	860.81	11.71	0.00	hazard	26.2%	0.001		0.0014 (0.0008-0.0023)
American Goldfinch (n=134)								
Audio/Visual	1412.26	0.00	0.77	hazard	15.9%	0.739	300	0.0391 (0.0286-0.0533)
Null	1414.75	2.49	0.22	neg. exp. <sup>h</sup>	17.9%	0.416		0.0762 (0.0537-0.1081)
Observer	1421.74	9.48	0.01	hazard	15.5%	0.762		0.0419 (0.0310-0.0566)
American Robin (n=152)								
Audio/Visual	1602.01	0.00	1.00	half-normal	16.0%	0.000	303	0.0413 (0.0302-0.0565)
Null	1626.22	24.21	0.00	hazard	22.4%	0.895		0.0563 (0.0364-0.0870)
Observer	1661.78	59.77	0.00	hazard	14.9%	0.000		0.0228 (0.0170-0.0305)
Wind	1662.91	60.90	0.00	half-normal	18.5%	0.000		0.0293 (0.0205-0.0421)
Barn Swallow (n=44)								
Observer	447.08	0.00	0.82	half-normal	27.5%	0.416	183	0.0089 (0.0052-0.0151)
Null	450.33	3.25	0.16	uniform	1.9%	0.610		0.0107 (0.0059-0.0193)
Audio/Visual	454.47	7.39	0.02	hazard	1.6%	0.416		0.0094 (0.0056-0.0159)
Bobolink (n=536)								
Null	5363.53	0.00	1.00	half-normal	12.6%	0.215	300	0.3028 (0.2368-0.3872)
Audio/Visual	5390.85	27.32	0.00	hazard	11.6%	0.000		0.1766 (0.1408-0.2216)
Observer	5390.93	27.40	0.00	hazard	11.6%	0.000		0.1766 (0.1407-0.2215)
Wind	5398.54	35.01	0.00	hazard	11.6%	0.000		0.1765 (0.1407-0.2215)

Table 5. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
Brown-headed Cowbird (n=175)								
Null	1764.45	0.00	1.00	hazard	21.7%	0.324	290	0.1481 (0.0972-0.2256)
Audio/Visual	1802.29	37.84	0.00	half-normal	16.4%	0.000		0.0535 (0.0389-0.0737)
Observer	1803.19	38.74	0.00	half-normal	16.4%	0.000		0.0534 (0.0388-0.0736)
Wind	1807.67	43.22	0.00	half-normal	26.0%	0.000		0.0643 (0.0389-0.1063)
Clay-colored Sparrow (n=175)								
Audio/Visual	1832.71	0.00	1.00	half-normal	17.3%	0.000	300	0.0854 (0.0609-0.1198)
Null	1874.89	42.18	0.00	hazard	21.6%	0.491		0.0855 (0.0562-0.1303)
Observer	1919.26	86.55	0.00	hazard	12.2%	0.000		0.0279 (0.0219-0.0354)
Wind	1927.79	95.08	0.00	hazard	12.4%	0.000		0.0279 (0.0219-0.0355)
Common Grackle (n=459)								
Null	5005.96	0.00	1.00	neg. exp. <sup>h</sup>	29.7%	0.015	400	0.1786 (0.1010-0.3158)
Wind	5187.68	181.72	0.00	half-normal	25.8%	0.000		0.0684 (0.0415-0.1127)
Audio/Visual	5189.81	183.85	0.00	half-normal	25.8%	0.000		0.0639 (0.0388-0.1052)
Observer	5208.24	202.28	0.00	hazard	25.7%	0.000		0.0483 (0.0293-0.0793)
Common Yellowthroat (n=241)								
Audio/Visual	2589.29	0.00	1.00	half-normal	13.7%	0.055	400	0.0443 (0.0339-0.0579)
Null	2624.08	34.79	0.00	neg. exp. <sup>h</sup>	15.2%	0.999		0.0489 (0.0363-0.0658)
Observer	2629.72	40.43	0.00	half-normal	10.1%	0.065		0.0329 (0.0270-0.0401)
Wind	2631.33	42.04	0.00	half-normal	10.2%	0.064		0.0339 (0.0277-0.0414)
Eastern Kingbird (n=96)								
Null	962.73	0.00	0.94	hazard	18.4%	0.414	400	0.0253 (0.0177-0.0363)
Audio/Visual	968.28	5.55	0.06	hazard	18.2%	0.289		0.0230 (0.0162-0.0329)
Wind	977.15	14.42	0.00	hazard	18.3%	0.386		0.0230 (0.0161-0.0329)



Table 5. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Field Sparrow (n=88)								
Wind	13.04	0.00	1.00	half-normal	none	0.316	350	0.0054 (0.0000-1.5692)
Audio/Visual	992.06	979.02	0.00	hazard	62.1%	0.742		0.0107 (0.0034-0.0332)
Observer	1007.09	994.05	0.00	half-normal	17.5%	0.575		0.0055 (0.0039-0.0078)
Null	1009.24	996.20	0.00	uniform	20.3%	0.840		0.0062 (0.0042-0.0092)
House Wren (n=34)								
Observer	352.59	0.00	0.33	hazard	27.4%	0.860	300	0.0037 (0.0022-0.0063)
Audio/Visual	352.59	0.00	0.33	hazard	27.4%	0.860		0.0037 (0.0022-0.0063)
Null	352.59	0.00	0.33	hazard	27.4%	0.860		0.0037 (0.0022-0.0063)
Wind	359.76	7.17	0.01	half-normal	32.3%	0.896		0.0063 (0.0034-0.0117)
Mourning Dove (n=105)								
Audio/Visual	1207.21	0.00	0.98	hazard	16.6%	0.883	402	0.0083 (0.0060-0.0115)
Wind	1215.57	8.36	0.02	half-normal	212.0%	0.168		0.0099 (0.0007-0.1213)
Null	1221.00	13.79	0.00	neg. exp. <sup>h</sup>	20.9%	0.838		0.0151 (0.0100-0.0226)
Observer	1225.30	18.09	0.00	half-normal	15.3%	0.298		0.0066 (0.0049-0.0089)
Northern Flicker (n=17)								
Audio/Visual	177.22	0.00	0.96	half-normal	41.2%	0.957	250	0.0051 (0.0023-0.0113)
Null	184.04	6.82	0.03	neg. exp. <sup>h</sup>	44.5%	0.949		0.0068 (0.0029-0.0160)
Wind	187.89	10.67	0.00	half-normal	130.5%	0.968		0.0043 (0.0005-0.0364)
Observer	189.76	12.54	0.00	hazard	40.8%	0.505		0.0026 (0.0012-0.0058)
Red-winged Blackbird (n=267)								
Audio/Visual	3026.92	0.00	1.00	half-normal	14.1%	0.003	400	0.0219 (0.0166-0.0288)
Null	3038.35	11.43	0.00	uniform	13.5%	0.183		0.0191 (0.0147-0.0249)
Observer	3041.18	14.26	0.00	half-normal	14.0%	0.000		0.0207 (0.0158-0.0273)
Wind	3041.77	14.85	0.00	half-normal	14.1%	0.000		0.0214 (0.0163-0.0282)

Table 5. continued.

Model	AICc <sup>a</sup>	ΔAICc <sup>b</sup>	w <sub>i</sub> <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	ρ <sup>g</sup>	Density (95% CI)
Ring-necked Pheasant (n=256)								
Observer	3020.49	0.00	1.00	half-normal	11.5%	0.013	500	0.0131 (0.0104-0.0164)
Audio/Visual	3043.36	22.87	0.00	half-normal	11.5%	0.013		0.0122 (0.0097-0.0153)
Null	3045.21	24.72	0.00	neg. exp. <sup>h</sup>	2.4%	0.244		0.0175 (0.0127-0.0241)
Wind	3054.22	33.73	0.00	half-normal	1.5%	0.013		0.0120 (0.0096-0.0150)
Savannah Sparrow (n=21)								
Wind	14.00	0.00	1.00	half-normal	77.0%	0.480	194	0.0038 (0.0009-0.0155)
Null	221.65	207.65	0.00	half-normal	51.9%	0.795		0.0080 (0.0030-0.0213)
Sedge Wren (n=195)								
Wind	10.32	0.00	1.00	half-normal	29.4%	0.583	240	0.0406 (0.0230-0.0717)
Audio/Visual	2033.62	2023.30	0.00	half-normal	22.7%	0.527		0.0539 (0.0347-0.0838)
Null	2037.80	2027.48	0.00	hazard	14.9%	0.961		0.0431 (0.0322-0.0578)
Observer	2040.41	2030.09	0.00	hazard	10.7%	0.576		0.0428 (0.0348-0.0528)
Song Sparrow (n=250)								
Audio/Visual	2803.34	0.00	1.00	half-normal	10.7%	0.000	400	0.0240 (0.0195-0.0296)
Null	2815.96	12.62	0.00	uniform	8.6%	0.098		0.0184 (0.0155-0.0217)
Observer	2820.31	16.97	0.00	half-normal	9.6%	0.000		0.0212 (0.0175-0.0256)
Wind	2827.35	24.01	0.00	half-normal	9.7%	0.000		0.0213 (0.0176-0.0257)
Tree Swallow (n=18)								
Audio/Visual	4.80	0.00	1.00	half-normal	61.8%	0.892	144	0.0083 (0.0027-0.0257)
Wind	19.64	14.84	0.00	half-normal	72.6%	0.367		0.0149 (0.0039-0.0560)
Null	171.87	167.07	0.00	uniform	53.0%	0.863		0.0093 (0.0035-0.0250)
Observer	173.49	168.69	0.00	half-normal	50.9%	0.948		0.0089 (0.0034-0.0229)

Table 5. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Western Meadowlark (n=68)								
Wind	13.38	0.00	1.00	half-normal	34.8%	0.572	541	0.0016 (0.0008-0.0032)
Audio/Visual	835.58	822.20	0.00	half-normal	39.2%	0.382		0.0041 (0.0019-0.0087)
Observer	849.41	836.03	0.00	half-normal	18.0%	0.382		0.0017 (0.0012-0.0024)
Null	851.34	837.96	0.00	neg. exp. <sup>h</sup>	26.5%	0.673		0.0031 (0.0019-0.0052)
Wild Turkey (n=39)								
Wind	9.18	0.00	1.00	half-normal	47.3%	0.071	400	0.0060 (0.0025-0.0146)
Null	451.03	441.85	0.00	hazard	92.2%	0.600		0.0289 (0.0060-0.1389)
Observer	467.20	458.02	0.00	half-normal	46.0%	0.000		0.0032 (0.0013-0.0075)

<sup>a</sup> AICc = Akaike's Information Criterion adjusted for small sample sizes

<sup>b</sup>  $\Delta$ AICc = relative adjustment of AICc

<sup>c</sup>  $w_i$  = Akaike weights

<sup>d</sup> Key function = model function shape selected as the best fit

<sup>e</sup> %CV = percent coefficient of variation

<sup>f</sup> GOF K-S p = p-value for Kolmogorov Smirnov goodness-of-fit test

<sup>g</sup>  $\rho$  = effective radius in meters

<sup>h</sup> Negative Exponential

Table 6. Model selection for bird density (birds/ha) based on radial distance estimation point counts at Homestead National Monument, Nebraska, USA, 2009. See methods section of chapter 2 for a description of models.

Model	AICc <sup>a</sup>	ΔAICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
American Crow (n=40)								
Wind	11.76	0.00	1.00	half-normal	82.5%	0.031	457	0.0016 (0.0004-0.0068)
Null	467.95	456.19	0.00	hazard	29.7%	0.06		0.0013 (0.0007-0.0021)
Observer	470.67	458.91	0.00	hazard	27.9%	0.031		0.0013 (0.0007-0.0021)
Audio/Visual	470.67	458.91	0.00	hazard	27.9%	0.031		0.0013 (0.0007-0.0021)
American Goldfinch (n=107)								
Audio/Visual	1028.45	0.00	0.97	half-normal	18.9%	0.376	160	0.0801 (0.0553-0.1158)
Null	1036.54	8.09	0.02	hazard	22.3%	0.993		0.0721 (0.0468-0.1112)
Wind	1037.52	9.07	0.01	hazard	24.2%	0.994		0.0779 (0.0487-0.1246)
Observer	1039.57	11.12	0.00	hazard	18.8%	0.686		0.0733 (0.0508-0.1058)
American Robin (n=133)								
Audio/Visual	1450.19	0.00	0.99	half-normal	16.1%	0.015	371	0.0365 (0.0266-0.0500)
Null	1459.03	8.84	0.01	neg. exp. <sup>h</sup>	18.3%	0.873		0.0800 (0.0560-0.1143)
Observer	1462.34	12.15	0.00	half-normal	15.8%	0.015		0.0331 (0.0243-0.0451)
wind	1466.63	16.44	0.00	half-normal	15.9%	0.015		0.0336 (0.0246-0.0458)
Baltimore Oriole (n=38)								
Audio/Visual	363.72	0.00	0.65	half-normal	26.3%	0.852	141	0.0291 (0.0175-0.0485)
Null	365.35	1.63	0.29	hazard	33.4%	0.715		0.0249 (0.0130-0.0474)
Observer	368.25	4.53	0.07	hazard	26.3%	0.572		0.0274 (0.0164-0.0456)
Wind	375.32	11.60	0.00	half-normal	28.3%	0.856		0.0270 (0.0156-0.0467)
Bell's Vireo (n=27)								
Audio/Visual	4.50	0.00	0.98	half-normal	103.6%	0.96	162	0.0221 (0.0038-0.1272)
Wind	12.86	8.36	0.02	half-normal	371.0%	0.57		0.0120 (0.0004-0.3598)
Null	274.43	269.93	0.00	neg. exp. <sup>h</sup>	42.4%	0.981		0.0184 (0.0081-0.0416)
Observer	276.07	271.57	0.00	half-normal	37.3%	0.96		0.0105 (0.0051-0.0216)

Table 6. continued.

Model	AICc <sup>a</sup>	ΔAICc <sup>b</sup>	w <sub>i</sub> <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	ρ <sup>g</sup>	Density (95% CI)
Brown-headed Cowbird (n=138)								
Audio/Visual	1396.97	0.00	1.00	hazard	15.9%	0.001	258	0.1137 (0.0833-0.1553)
Observer	1438.61	41.64	0.00	hazard	15.1%	0.01		0.0769 (0.0573-0.1034)
Wind	1439.18	42.21	0.00	neg. exp. <sup>h</sup>	18.1%	0.1		0.1319 (0.0926-0.1878)
Blue Jay (n=29)								
Audio/Visual	329.67	0.00	0.54	half-normal	33.1%	0.733	326	0.0034 (0.0018-0.0064)
Null	330.63	0.96	0.33	uniform	26.8%	0.743		0.0027 (0.0016-0.0046)
Observer	333.21	3.54	0.09	half-normal	29.6%	0.675		0.0029 (0.0016-0.0052)
Wind	334.90	5.23	0.04	half-normal	31.2%	0.767		0.0032 (0.0018-0.0059)
Brown Thrasher (n=38)								
Null	397.17	0.00	0.63	neg. exp. <sup>h</sup>	33.6%	0.613	252	0.0476 (0.0249-0.0907)
Observer	398.38	1.21	0.34	half-normal	34.2%	0.219		0.0239 (0.0124-0.0461)
Audio/Visual	403.77	6.60	0.02	hazard	30.9%	0.243		0.0192 (0.0106-0.0349)
Wind	407.76	10.59	0.00	half-normal	34.5%	0.305		0.0226 (0.0116-0.0437)
Common Yellowthroat (n=268)								
Audio/Visual	2691.30	0.00	1.00	half-normal	9.5%	0.034	313	0.1703 (0.1413-0.2052)
Null	2722.04	30.74	0.00	hazard	9.0%	0.372		0.1148 (0.0963-0.1370)
Observer	2728.12	36.82	0.00	hazard	7.8%	0.037		0.0971 (0.0834-0.1131)
Wind	2736.49	45.19	0.00	hazard	7.8%	0.037		0.0971 (0.0833-0.1131)
Dickcissel (n=715)								
Audio/Visual	7313.03	0.00	1.00	hazard	6.2%	0.347	371	0.2524 (0.2233-0.2852)
Null	7513.24	200.21	0.00	half-normal	5.9%	0.663		0.2545 (0.2268-0.2855)
Wind	7521.47	208.44	0.00	half-normal	5.5%	0.005		0.2245 (0.2014-0.2503)
Observer	7521.57	208.54	0.00	half-normal	5.5%	0.004		0.2226 (0.1997-0.2481)

Table 6. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
Eastern Kingbird (n=53)								
Audio/Visual	516.20	0.00	0.96	hazard	26.6%	0.936	192	0.0483 (0.0289-0.0808)
Null	523.02	6.82	0.03	hazard	33.3%	0.987		0.0487 (0.0257-0.0925)
Observer	526.02	9.82	0.01	hazard	26.3%	0.577		0.0532 (0.0319-0.0885)
Wind	531.90	15.70	0.00	hazard	26.5%	0.971		0.0440 (0.0263-0.0735)
Gray Catbird (n=145)								
Null	1403.67	0.00	0.92	hazard	16.6%	0.731	249	0.1427 (0.1033-0.1972)
Wind	1408.70	5.03	0.07	half-normal	20.1%	0.000		0.1370 (0.0926-0.2028)
Audio/Visual	1418.31	14.64	0.00	half-normal	13.8%	0.000		0.1179 (0.0900-0.1545)
Observer	1423.01	19.34	0.00	hazard	13.5%	0.000		0.0856 (0.0657-0.1115)
House Wren (n=122)								
Audio/Visual	1206.02	0.00	0.85	half-normal	18.8%	0.35	198	0.0960 (0.0665-0.1387)
Observer	1210.83	4.81	0.08	hazard	14.9%	0.904		0.0802 (0.0600-0.1073)
Null	1211.11	5.09	0.07	hazard	18.6%	0.93		0.0842 (0.0585-0.1212)
Wind	1217.80	11.78	0.00	hazard	15.6%	0.545		0.0862 (0.0636-0.1169)
Mourning Dove (n=105)								
Observer	1211.71	0.00	0.80	hazard	14.5%	0.943	389	0.0082 (0.0062-0.0108)
Audio/Visual	1214.69	2.98	0.18	half-normal	15.5%	0.916		0.0096 (0.0071-0.0130)
Null	1219.31	7.60	0.02	uniform	11.5%	0.798		0.0073 (0.0059-0.0092)
Wind	1222.75	11.04	0.00	half-normal	214.0%	0.999		0.0098 (0.0007-0.1317)
Northern Bobwhite (n=65)								
Wind	13.45	0.00	1.00	half-normal	773.6%	0.281	390	0.0044 (0.0001-0.2550)
Null	756.96	743.51	0.00	uniform	13.1%	0.995		0.0042 (0.0032-0.0054)
Audio/Visual	758.05	744.60	0.00	half-normal	18.3%	0.985		0.0045 (0.0032-0.0065)
Observer	759.48	746.03	0.00	half-normal	15.3%	0.927		0.0046 (0.0034-0.0062)

Table 6. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho^g$	Density (95% CI)
Northern Cardinal (n=63)								
Audio/Visual	710.60	0.00	0.99	half-normal	31.9%	0.973	366	0.0106 (0.0057-0.0196)
Null	720.54	9.94	0.01	half-normal	19.7%	0.771		0.0072 (0.0049-0.0106)
Observer	722.64	12.04	0.00	half-normal	18.9%	0.974		0.0072 (0.0050-0.0105)
Northern Flicker (n=31)								
Wind	15.50	0.00	1.00	half-normal	128.5%	0.926	220	0.0083 (0.0011-0.0629)
Null	330.64	315.14	0.00	uniform	36.5%	0.952		0.0087 (0.0043-0.0176)
Observer	333.72	318.22	0.00	half-normal	719.1%	0.773		0.0074 (0.0001-0.4369)
Audio/Visual	335.24	319.74	0.00	hazard	31.9%	0.773		0.0077 (0.0042-0.0143)
Red-bellied Woodpecker (n=17)								
Wind	7.85	0.00	1.00	half-normal	none	0.48	183	0.0044 (0.0000-1.0293)
Null	173.32	165.47	0.00	uniform	34.7%	0.566		0.0047 (0.0024-0.0092)
Observer	175.23	167.38	0.00	half-normal	45.9%	0.615		0.0061 (0.0025-0.0146)
Audio/Visual	175.84	167.99	0.00	half-normal	none	0.615		0.0060 (0.0001-0.7044)
Red-winged Blackbird (n=350)								
Null	3781.91	0.00	1.00	neg. exp. <sup>h</sup>	16.7%	0.76	358	0.4843 (0.3500-0.6702)
Wind	3867.17	85.26	0.00	half-normal	12.1%	0.00		0.1064 (0.0839-0.1349)
Observer	3881.39	99.48	0.00	hazard	12.0%	0.00		0.0886 (0.0701-0.1120)

Table 6. continued.

Model	AICc <sup>a</sup>	$\Delta$ AICc <sup>b</sup>	$w_i$ <sup>c</sup>	Key function <sup>d</sup>	%CV <sup>e</sup>	GOF K-S p <sup>f</sup>	$\rho$ <sup>g</sup>	Density (95% CI)
Ring-necked Pheasant (n=129)								
Null	1516.73	0.00	0.65	uniform	46.3%	0.41	437	0.0040 (0.0017-0.0096)
Observer	1519.37	2.64	0.17	hazard	15.3%	0.293		0.0035 (0.0026-0.0048)
Audio/Visual	1519.37	2.64	0.17	hazard	15.3%	0.293		0.0035 (0.0026-0.0048)
Wind	1528.11	11.38	0.00	hazard	15.4%	0.293		0.0035 (0.0026-0.0048)

<sup>a</sup> AICc = Akaike's Information Criterion adjusted for small sample sizes

<sup>b</sup>  $\Delta$ AICc = relative adjustment of AICc

<sup>c</sup>  $w_i$  = Akaike weights

<sup>d</sup> Key function = model function shape selected as the best fit

<sup>e</sup> %CV = percent coefficient of variation

<sup>f</sup> GOF K-S p = p-value for Kolmogorov Smirnov goodness-of-fit test

<sup>g</sup>  $\rho$  = effective radius in meters

<sup>h</sup> Negative Exponential



Table 7. Number of recorded observations per species for 7 repeated point surveys for 40 points at Tallgrass Prairie National Preserve, Kansas (T), 58 points at Pipestone National Monument, Minnesota (P), and 34 points at Homestead National Monument, Nebraska (H), May-August of 2008 and 2009.

Species	2008			2009		
	T	P	H	T	P	H
Alder Flycatcher ( <i>Empidonax alnorum</i> )	- <sup>a</sup>	-	-	-	-	1
American Crow ( <i>Corvus brachyrhynchos</i> )	23	158	6	30	79	50
American Goldfinch ( <i>Carduelis tristis</i> )	2	290	121	-	330	223
American Redstart ( <i>Setophaga ruticilla</i> )	-	1	-	-	-	-
American Robin ( <i>Turdus migratorius</i> )	-	110	38	-	164	164
Baltimore Oriole ( <i>Icterus galbula</i> )	2	-	63	1	2	57
Bank Swallow ( <i>Riparia riparia</i> )	4	19	-	3	15	-
Barn Swallow ( <i>Hirundo rustica</i> )	45	238	7	24	86	15
Bell's Vireo ( <i>Vireo bellii</i> )	-	-	-	-	-	27
Belted Kingfisher ( <i>Megaceryle alcyon</i> )	-	10	-	-	4	-
Black-and-White Warbler ( <i>Mniotilta varia</i> )	-	-	-	-	1	-
Black-capped Chickadee ( <i>Poecile atricapillus</i> )	-	-	1	-	-	-
Blue Grosbeak ( <i>Cyanoloxia glaucoerulea</i> )	3	6	-	-	-	-
Blue Jay ( <i>Cyanocitta cristata</i> )	16	22	2	-	8	28
Blue-winged Teal ( <i>Anas discors</i> )	-	3	-	-	-	1
Bobolink ( <i>Dolichonyx oryzivorus</i> )*	-	408	-	-	524	-
Brown Thrasher ( <i>Toxostoma rufum</i> )	5	4	45	10	16	39
Brown-headed Cowbird ( <i>Molothrus ater</i> )	534	253	181	354	194	280
Canada Goose ( <i>Branta canadensis</i> )	6	30	3	2	13	1
Chimney Swift ( <i>Chaetura pelagica</i> )	-	5	-	-	13	14
Chipping Sparrow ( <i>Spizella passerina</i> )	-	10	-	-	14	8
Clay-colored Sparrow ( <i>Spizella pallida</i> )	-	125	-	-	159	-
Cliff Swallow ( <i>Petrochelidon pyrrhonota</i> )	-	23	-	6	34	-
Common Grackle ( <i>Quiscalus quiscula</i> )	2	463	1	-	526	17
Common Nighthawk ( <i>Chordeiles minor</i> )	61	42	-	60	69	-
Common Yellowthroat ( <i>Geothlypis trichas</i> )	1	82	193	-	240	286
Dickcissel ( <i>Spiza americana</i> )*	960	122	386	775	-	748
Downy Woodpecker ( <i>Picoides pubescens</i> )	-	-	-	-	1	2
Eastern Bluebird ( <i>Sialia sialis</i> )	2	14	13	-	10	5
Eastern Kingbird ( <i>Tyrannus tyrannus</i> )	9	121	43	4	96	63
Eastern Meadowlark ( <i>Sturnella magna</i> )*	920	-	19	720	-	-
Eastern Phoebe ( <i>Sayornis phoebe</i> )	-	6	2	-	-	12
Eastern Towhee ( <i>Pipilo erythrophthalmus</i> )	-	-	1	-	-	9
Eastern Wood-Pewee ( <i>Contopus virens</i> )	3	-	16	3	-	10

Table 7. continued.

Species	2008			2009		
	T	P	H	T	P	H
European Starling ( <i>Sturnus vulgaris</i> )	-	3	-	-	28	13
Field Sparrow ( <i>Spizella pusilla</i> )	22	34	2	2	90	4
Grasshopper Sparrow ( <i>Ammodramus savannarum</i> )*	547	8	3	356	1	-
Gray Catbird ( <i>Dumetella carolinensis</i> )	-	28	118	-	12	186
Great Blue Heron ( <i>Ardea herodias</i> )	3	6	3	4	8	11
Great Egret ( <i>Ardea alba</i> )	-	1	-	-	-	-
Greater Prairie Chicken ( <i>Tympanuchus cupido</i> )*	12	-	-	9	-	-
Green Heron ( <i>Butorides virescens</i> )	-	5	-	-	10	-
Hairy Woodpecker ( <i>Picoides villosus</i> )	-	-	-	-	-	1
Henslow's Sparrow ( <i>Ammodramus henslowii</i> )*	-	-	-	58	-	-
Horned Lark ( <i>Eremophila alpestris</i> )*	4	-	-	-	-	-
House Finch ( <i>Carpodacus mexicanus</i> )	-	-	-	-	1	-
House Sparrow ( <i>Passer domesticus</i> )	-	-	-	-	1	-
House Wren ( <i>Troglodytes aedon</i> )	-	12	9	-	33	124
Indigo Bunting ( <i>Passerina cyanea</i> )	-	-	1	-	1	1
Killdeer ( <i>Charadrius vociferus</i> )	23	71	-	9	11	3
Lark Sparrow ( <i>Chondestes grammacus</i> )*	12	1	2	-	-	-
Least Flycatcher ( <i>Empidonax minimus</i> )	2	1	-	-	-	-
Loggerhead Shrike ( <i>Lanius ludovicianus</i> )	1	-	-	-	-	-
Mallard ( <i>Anas platyrhynchos</i> )	2	5	-	-	16	-
Marsh Wren ( <i>Cistothorus palustris</i> )	-	2	7	-	-	-
Mourning Dove ( <i>Zenaida macroura</i> )	63	114	24	70	166	142
N. Rough-winged Swallow ( <i>Stelgidopteryx serripennis</i> )	32	38	1	49	9	32
Northern Bobwhite ( <i>Colinus virginianus</i> )	94	-	7	119	-	66
Northern Cardinal ( <i>Cardinalis cardinalis</i> )	1	-	-	-	-	66
Northern Flicker ( <i>Colaptes auratus</i> )	2	62	1	1	19	35
Northern Harrier ( <i>Circus cyaneus</i> )*	1	-	-	-	2	-
Northern Mockingbird ( <i>Mimus polyglottos</i> )	6	-	-	-	-	-
Orchard Oriole ( <i>Icterus spurius</i> )	8	8	-	8	3	9
Purple Martin ( <i>Progne subis</i> )	-	4	-	-	22	-
Red-bellied Woodpecker ( <i>Melanerpes carolinus</i> )	2	-	-	-	1	19
Red-headed Woodpecker ( <i>Melanerpes erythrocephalus</i> )	-	2	6	-	1	3
Red-tailed Hawk ( <i>Buteo jamaicensis</i> )	1	6	4	-	7	6
Red-winged Blackbird ( <i>Agelaius phoeniceus</i> )	71	600	418	155	233	482

Table 7. continued.

Species	2008			2009		
	T	P	H	T	P	H
Ring-necked Pheasant ( <i>Phasianus colchicus</i> )*	-	383	44	-	250	151
Rose-breasted Grosbeak ( <i>Pheucticus ludovicianus</i> )	-	-	-	-	-	8
Savannah Sparrow ( <i>Passerculus sandwichensis</i> )*	-	31	-	-	21	-
Sedge Wren ( <i>Cistothorus platensis</i> )*	-	95	1	-	189	-
Song Sparrow ( <i>Melospiza melodia</i> )	-	76	18	-	248	9
Swainson's Hawk ( <i>Buteo swainsoni</i> )	1	-	-	-	-	-
Tree Swallow ( <i>Tachycineta bicolor</i> )	33	41	-	-	43	-
Turkey Vulture ( <i>Cathartes aura</i> )	16	3	10	4	-	8
Upland Sandpiper ( <i>Bartramia longicauda</i> )*	207	-	-	206	7	-
Vesper Sparrow ( <i>Pooecetes gramineus</i> )*	-	2	-	-	-	-
Warbling Vireo ( <i>Vireo gilvus</i> )	-	-	-	-	-	2
Western Kingbird ( <i>Tyrannus verticalis</i> )	-	1	-	-	-	-
Western Meadowlark ( <i>Sturnella neglecta</i> )*	12	218	1	-	70	-
White-breasted Nuthatch ( <i>Sitta carolinensis</i> )	-	-	-	-	-	2
White-throated Sparrow ( <i>Zonotrichia albicollis</i> )	-	-	4	-	-	-
Wild Turkey ( <i>Meleagris gallopavo</i> )	3	15	4	-	25	9
Yellow Warbler ( <i>Dendroica aestiva</i> )	-	15	-	-	6	-
Yellow-billed Cuckoo ( <i>Coccyzus americanus</i> )	3	-	-	-	-	-
Yellow-headed Blackbird ( <i>Xanthocephalus xanthocephalus</i> )	-	3	-	-	1	-
Total	3782	4459	1829	3042	4133	3452

<sup>a</sup> No observation

\*denotes grassland obligate species

Table 8. Vegetation measurements at grassland bird survey points at Tallgrass Prairie National Preserve, Kansas, USA, in 2008. Listed for each Heartland Inventory and Monitoring Network point name (Point) is average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T002	28-May	110.00	<1	10	60	10	30	1.31	0.19	3.50	2.52	0
T004	28-May	400.00	0	10	60	10	20	0.15	0.13	0.19	0.43	0
T005	28-May	500.00	0	15	40	15	40	0.31	0.25	0.38	0.40	0
T009	28-May	444.00	0	40	40	5	20	0.10	0.00	0.19	1.80	0
T010	28-May	434.00	0	35	50	25	40	0.25	0.06	0.50	1.75	0
T012	28-May	907.00	0	20	50	5	30	0.13	0.06	0.19	1.00	0
T013	28-May	762.00	0	15	40	30	40	0.04	0.00	0.13	3.00	0
T025	4-Jun	25.00	0	5	60	75	5	1.32	1.00	1.53	0.40	2
T027	4-Jun	450.00	0	60	20	40	10	1.19	0.88	1.69	0.68	2
T028	4-Jun	38.50	0	15	65	80	<1	1.79	1.44	2.19	0.42	2
T032	4-Jun	325.00	0	45	30	80	<1	1.56	1.19	2.25	0.68	2
T033	4-Jun	200.00	0	35	55	70	<1	2.06	1.69	2.31	0.30	2
T035	4-Jun	200.00	0	20	25	95	<1	1.42	1.31	1.56	0.18	2
T036	4-Jun	250.00	0	15	65	70	<1	1.10	0.06	1.75	1.53	2
T042	30-May	125.00	0	5	20	80	10	1.29	1.13	1.63	0.39	1
T044	30-May	300.00	0	15	20	60	55	0.90	0.50	1.25	0.84	1
T047	30-May	100.00	0	10	65	80	0	1.06	0.63	1.31	0.65	1
T049	30-May	10.00	0	40	65	50	10	1.65	1.31	2.19	0.53	1
T053	30-May	500.00	0	30	45	80	<1	1.08	0.88	1.25	0.35	1
T055	30-May	794.00	0	20	65	70	5	0.90	0.38	1.25	0.98	1
T058	30-May	287.50	0	15	25	40	30	0.75	0.44	1.00	0.75	1

Table 8. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T060	30-May	944.00	0	30	40	60	15	0.94	0.81	1.06	0.27	1
T087	27-May	250.00	0	15	15	50	40	0.29	0.13	0.38	0.86	0
T089	27-May	235.00	0	10	60	<1	50	0.46	0.06	1.06	2.18	0
T091	27-May	500.00	0	50	10	15	40	0.42	0.13	0.88	1.80	0
T093	27-May	400.00	0	80	15	15	10	0.71	0.50	1.00	0.71	0
T098	27-May	422.00	0	85	10	20	5	0.35	0.31	0.44	0.35	0
T099	27-May	250.00	0	20	40	20	30	0.29	0.13	0.38	0.86	0
T101	27-May	400.00	0	40	15	40	20	0.27	0.06	0.44	1.38	0
T104	27-May	247.50	0	10	15	25	75	0.54	0.50	0.56	0.12	0
T114	3-Jun	172.50	0	60	60	40	<1	1.00	0.75	1.31	0.56	1
T118	3-Jun	250.00	0	30	90	50	5	1.77	1.31	2.13	0.46	1
T123	3-Jun	180.00	0	30	80	30	<1	1.08	0.69	1.50	0.75	3
T128	3-Jun	165.00	<1	15	70	70	0	1.58	1.50	1.69	0.12	3
T136	3-Jun	120.00	0	10	90	40	0	1.56	1.25	2.00	0.48	1
T140	3-Jun	400.00	0	20	80	50	0	1.44	1.13	1.63	0.35	1
T145	3-Jun	403.00	0	20	40	95	0	1.21	0.94	1.63	0.57	3
T150	3-Jun	150.00	<1	15	40	85	0	1.63	1.44	1.94	0.31	1
T183	28-May	187.50	0	20	50	20	50	0.13	0.00	0.19	1.50	0
T190	4-Jun	458.00	0	10	35	60	20	0.77	0.44	1.25	1.05	2
T002	17-Jul	25.00	<1	30	60	5	10	2.90	1.63	3.69	0.71	0
T004	17-Jul	120.00	0	20	65	5	10	1.46	1.25	1.69	0.30	0
T005	16-Jul	350.00	0	5	70	5	35	0.75	0.38	1.13	1.00	0
T009	17-Jul	65.00	0	25	65	<1	10	1.06	0.94	1.31	0.35	0
T010	16-Jul	202.50	0	20	55	5	35	1.02	0.75	1.25	0.49	0
T012	17-Jul	907.00	0	20	65	<1	15	0.46	0.25	0.88	1.36	0

Table 8. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T013	16-Jul	500.00	0	15	20	5	50	0.35	0.06	0.94	2.47	0
T025	11-Jul	252.00	0	35	65	10	5	1.50	0.94	2.00	0.71	2
T027	11-Jul	400.00	<1	55	80	30	<1	1.42	0.75	2.13	0.97	2
T028	11-Jul	206.00	0	100	30	25	0	2.56	2.38	2.81	0.17	2
T032	11-Jul	386.00	0	95	50	50	<1	2.71	2.44	2.94	0.18	2
T033	11-Jul	100.00	0	80	50	40	<1	2.50	2.06	2.94	0.35	2
T035	11-Jul	95.00	0	90	70	30	0	3.08	2.88	3.25	0.12	2
T036	11-Jul	100.00	0	50	50	65	<1	0.67	0.38	1.19	1.22	2
T042	24-Jul	130.00	0	10	80	95	<1	2.56	1.94	3.63	0.66	1
T044	22-Jul	225.00	0	25	60	65	20	1.75	1.50	1.94	0.25	1
T047	24-Jul	112.50	0	25	100	85	0	2.65	2.06	3.25	0.45	1
T049	24-Jul	13.00	0	10	95	85	15	2.23	1.69	2.63	0.42	1
T053	24-Jul	425.00	0	70	40	55	<1	2.08	1.75	2.38	0.30	1
T055	23-Jul	794.00	0	15	95	40	<1	2.52	2.31	2.75	0.17	1
T058	24-Jul	275.00	0	10	20	55	20	2.73	2.63	2.94	0.11	1
T060	23-Jul	944.00	0	65	95	40	<1	2.71	1.25	3.81	0.95	1
T087	17-Jul	455.00	<1	20	55	<1	10	0.98	0.88	1.19	0.32	0
T089	18-Jul	15.00	0	20	90	10	<1	2.04	0.56	3.13	1.26	0
T091	17-Jul	365.00	0	35	75	20	10	1.28	1.00	1.63	0.49	0
T093	18-Jul	361.00	0	35	40	10	20	1.88	1.13	2.44	0.70	0
T098	17-Jul	422.00	<1	35	75	20	<1	2.35	1.56	3.31	0.74	0
T099	18-Jul	507.00	<1	20	50	<1	20	0.90	0.44	1.31	0.98	0
T101	17-Jul	200.00	0	35	35	<1	15	1.04	0.63	1.38	0.72	0
T104	18-Jul	378.00	0	10	55	5	15	0.83	0.69	1.06	0.45	0
T114	25-Jul	77.50	0	25	95	5	<1	2.02	1.75	2.19	0.22	1

Table 8. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T118	25-Jul	649.00	0	15	95	40	<1	2.27	2.13	2.44	0.14	1
T123	24-Jul	47.50	0	20	70	85	10	1.69	1.38	2.19	0.48	3
T128	25-Jul	22.50	0	15	90	25	<1	2.29	1.56	3.19	0.71	3
T136	18-Jul	30.00	0	5	100	20	5	2.00	1.69	2.19	0.25	1
T140	25-Jul	689.00	0	20	100	30	<1	2.38	1.56	3.31	0.74	1
T145	24-Jul	425.00	0	35	20	85	5	1.25	0.69	1.56	0.70	3
T150	25-Jul	246.00	0	35	90	45	<1	3.02	2.06	3.94	0.62	1
T183	17-Jul	51.67	0	10	55	5	10	0.77	0.50	1.25	0.97	0
T190	11-Jul	458.00	0	90	35	40	<1	2.02	1.44	2.63	0.59	2

Table 9. Vegetation measurements at grassland bird survey points at Pipestone National Monument, Minnesota, USA, in 2008. Listed for each Heartland Inventory and Monitoring Network point name (Point) is average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P01	22-May	79.75	0	25	30	95	5	1.69	1.06	2.81	1.04	1
P02	22-May	68.50	0	25	30	95	0	0.31	0.25	0.44	0.60	1
P03	21-May	41.00	<1	10	35	95	<1	0.65	0.56	0.69	0.19	1
P05	22-May	66.25	5	10	85	95	<1	0.73	0.63	0.94	0.43	1
P06	23-May	62.75	5	5	75	90	<1	1.48	0.94	2.31	0.93	1
P07	21-May	88.00	<1	15	20	80	5	0.83	0.75	0.94	0.23	1
P08	22-May	145.00	10	30	30	80	10	1.44	0.63	2.13	1.04	1
P10	4-Jun	153.67	0	<1	30	85	10	0.81	0.38	1.06	0.85	0
P11	4-Jun	126.50	0	50	30	95	0	1.29	0.75	2.13	1.06	0
P12	21-May	79.75	0	10	55	95	<1	1.60	0.25	3.19	1.83	1
P13	21-May	145.00	<1	10	55	85	<1	0.92	0.81	1.06	0.27	1
P14	22-May	100.00	<1	5	35	90	5	0.63	0.50	0.81	0.50	1
P15	23-May	59.00	5	<1	90	95	0	0.67	0.31	1.31	1.50	1
P16	9-Jun	164.25	<1	5	55	90	<1	0.94	0.63	1.50	0.93	0
P17	4-Jun	185.00	0	5	55	95	0	0.71	0.38	1.06	0.97	0
P18	4-Jun	2.50	0	20	10	90	5	2.15	0.25	5.13	2.27	0
P19	21-May	67.00	5	25	25	65	15	1.00	0.50	1.88	1.38	1
P20	22-May	39.75	<1	10	15	90	<1	0.88	0.75	1.06	0.36	1
P22	23-May	67.25	0	0	75	100	0	1.69	1.50	1.81	0.19	1
P23	9-Jun	201.33	0	10	60	90	<1	0.58	0.56	0.63	0.11	0
P24	4-Jun	132.50	<1	5	45	95	0	0.58	0.50	0.69	0.32	0
P25	4-Jun	37.25	0	0	5	95	<1	0.77	0.31	1.31	1.30	0



Table 9. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P26	23-May	79.50	5	20	45	80	5	0.83	0.69	1.06	0.45	0
P29	23-May	48.50	0	0	95	95	0	3.21	2.63	4.25	0.51	2
P30	9-Jun	145.00	<1	20	60	80	15	0.58	0.50	0.69	0.32	0
P31	7-Jun	102.50	10	60	85	10	10	0.52	0.31	0.63	0.60	0
P32	4-Jun	105.50	<1	5	65	90	<1	0.46	0.25	0.63	0.82	0
P35	23-May	23.25	<1	25	5	25	30	0.63	0.44	0.81	0.60	2
P37	7-Jun	85.00	0	20	50	80	10	0.46	0.31	0.56	0.55	0
P38	4-Jun	155.50	<1	5	20	95	<1	0.65	0.38	0.81	0.68	0
P41	26-May	57.50	<1	20	75	90	<1	1.17	0.56	1.69	0.96	2
P42	9-Jun	93.00	5	10	85	80	10	0.83	0.75	0.88	0.15	0
P43	7-Jun	71.00	0	5	75	95	<1	0.44	0.31	0.63	0.71	0
P44	28-May	35.50	0	<1	55	95	<1	1.85	1.19	2.38	0.64	2
P45	26-May	53.00	35	<1	60	95	0	1.60	0.63	3.25	1.64	2
P46	26-May	157.50	<1	0	95	95	0	1.81	1.75	1.88	0.07	2
P47	15-Jun	210.25	<1	60	50	5	60	1.00	0.63	1.44	0.81	0
P48	15-Jun	188.75	0	5	75	65	25	0.63	0.50	0.81	0.50	0
P49	28-May	39.00	<1	5	90	90	0	1.58	0.25	2.69	1.54	2
P50	26-May	136.00	0	10	80	95	0	1.79	0.81	3.00	1.22	2
P51	15-Jun	137.33	0	25	75	65	10	0.83	0.69	1.06	0.45	0
P52	15-Jun	168.50	0	10	50	50	15	0.79	0.63	0.94	0.39	0
P53	29-May	83.50	5	<1	85	95	0	2.10	1.44	3.00	0.74	2
P54	26-May	76.75	0	0	85	85	0	3.00	2.19	3.56	0.46	2
P55	18-Jun	83.67	5	65	45	85	5	1.04	0.81	1.31	0.48	0
P56	15-Jun	4.75	0	10	55	90	5	0.81	0.69	0.94	0.31	0
P57	29-May	109.50	20	20	50	95	<1	1.77	1.38	2.38	0.56	2
P58	29-May	3.00	<1	<1	85	95	0	0.38	0.25	0.63	1.00	2

Table 9. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P59	26-May	111.50	0	20	5	15	80	1.35	0.69	2.19	1.11	2
P60	18-Jun	120.75	0	25	80	80	5	1.00	0.56	1.50	0.94	0
P61	15-Jun	173.25	0	10	50	80	10	0.79	0.69	0.88	0.24	0
P62	29-May	118.33	5	0	85	90	10	1.83	1.44	2.63	0.65	2
P63	28-May	49.25	5	5	80	95	0	1.10	0.31	1.88	1.42	2
P64	18-Jun	175.33	5	<1	75	30	5	1.15	0.63	1.69	0.93	0
P65	17-Jun	165.50	0	5	80	95	5	0.79	0.50	1.00	0.63	0
P66	28-May	115.00	0	95	5	25	<1	0.58	0.25	0.75	0.86	2
P67	18-Jun	89.50	0	5	80	85	5	0.96	0.94	1.00	0.07	0
P68	17-Jun	123.50	1	5	80	85	5	1.10	0.69	1.56	0.79	0
P01	22-Jul	89.00	0	30	40	95	<1	3.56	1.69	5.69	1.12	1
P02	22-Jul	102.50	0	5	5	95	0	0.71	0.00	1.31	1.85	1
P03	15-Jul	106.50	5	25	30	55	<1	2.31	1.38	3.44	0.89	1
P05	18-Jul	128.25	0	30	40	85	10	3.52	3.06	3.81	0.21	1
P06	22-Jul	104.00	0	55	40	90	5	4.92	3.81	6.88	0.62	1
P07	16-Jul	163.25	10	10	55	85	<1	3.98	3.31	4.88	0.39	1
P08	18-Jul	137.50	10	30	50	90	<1	3.88	3.00	4.31	0.34	1
P10	21-Jul	125.75	<1	5	80	75	5	2.48	2.13	2.81	0.28	0
P11	21-Jul	14.25	0	0	55	85	0	1.73	1.31	2.38	0.61	0
P12	15-Jul	134.00	0	75	45	95	0	3.60	0.00	7.50	2.08	1
P13	16-Jul	77.50	5	10	90	95	0	4.60	4.19	4.94	0.16	1
P14	16-Jul	89.50	<1	10	20	75	10	3.75	3.31	4.13	0.22	1
P15	18-Jul	78.75	0	5	10	30	5	2.63	0.25	4.75	1.71	1
P16	21-Jul	185.25	0	5	95	80	<1	2.67	1.75	3.13	0.52	0
P17	21-Jul	140.50	<1	25	45	10	20	1.17	0.00	2.06	1.77	0
P18	20-Jul	1.75	0	50	60	75	10	9.31	8.94	9.50	0.06	0

Table 9. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P19	15-Jul	67.75	5	25	15	50	5	2.88	1.63	3.94	0.80	1
P20	16-Jul	80.00	0	20	90	90	0	4.60	4.19	5.25	0.23	1
P22	18-Jul	42.25	0	0	80	95	0	4.60	3.25	5.75	0.54	1
P23	21-Jul	201.67	0	40	40	75	5	2.71	2.38	3.19	0.30	0
P24	21-Jul	117.25	15	10	80	5	20	2.27	1.44	2.88	0.63	0
P25	20-Jul	39.00	0	<1	75	50	15	7.54	6.00	8.50	0.33	0
P29	18-Jul	62.50	0	0	95	90	5	5.42	4.44	6.88	0.45	2
P30	22-Jul	127.75	30	10	75	80	5	2.94	2.56	3.38	0.28	0
P31	22-Jul	166.25	10	40	25	50	20	2.10	1.81	2.38	0.27	0
P32	19-Jul	72.67	5	15	75	5	75	2.23	1.56	2.69	0.50	0
P35	18-Jul	7.00	0	15	30	75	<1	2.21	1.75	2.81	0.48	2
P36	15-Jul	49.00	75	20	75	70	5	3.50	2.75	4.06	0.38	0
P37	22-Jul	138.50		25	50	10	20	2.67	1.81	3.81	0.75	0
P38	17-Jul	108.25	10	5	75	80	5	1.71	1.56	1.88	0.18	0
P41	18-Jul	146.50	5	30	5	50	15	2.83	2.19	4.06	0.66	2
P42	22-Jul	31.25	25	30	65	30	50	2.85	2.50	3.38	0.31	0
P43	22-Jul	70.00	0	45	75	15	15	1.81	1.31	2.13	0.45	0
P44	17-Jul	49.25	5	5	45	95	<1	4.02	2.69	5.38	0.67	2
P45	18-Jul	70.00	0	30	15	90	5	3.42	0.25	7.00	1.98	2
P46	18-Jul	240.25	5	10	80	90	0	3.44	2.31	4.88	0.75	2
P47	24-Jul	123.25	5	75	10	50	20	3.29	2.19	4.31	0.65	0
P48	22-Jul	74.75	0	<1	75	90	5	1.67	1.50	1.88	0.23	0
P49	17-Jul	22.75	5	10	85	90	<1	5.25	4.75	6.13	0.26	2
P50	18-Jul	258.25	5	10	75	95	<1	2.83	1.56	4.38	0.99	2
P51	24-Jul	28.00	5	15	80	75	10	3.21	2.25	4.25	0.62	0
P52	22-Jul	131.00	0	45	75	90	<1	2.81	1.63	3.94	0.82	0

Table 9. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P53	17-Jul	125.00	0	10	30	90	5	3.46	3.31	3.56	0.07	2
P54	19-Jul	237.25	0	5	50	75	5	11.33	9.81	14.25	0.39	2
P55	23-Jul	140.75	15	60	70	50	10	3.29	2.69	4.00	0.40	0
P56	24-Jul	2.75	5	5	60	95	<1	3.52	1.94	6.19	1.21	0
P57	19-Jul	140.75	5	5	20	90	5	4.65	2.25	6.38	0.89	2
P58	19-Jul	3.75	0	5	45	95	0	2.28	1.31	3.25	0.85	2
P59	19-Jul	193.75	0	10	5	95	<1	2.69	0.31	4.69	1.63	2
P60	23-Jul	28.25	0	40	75	50	10	2.21	2.13	2.25	0.06	0
P61	24-Jul	183.00	0	30	80	75	10	2.29	2.13	2.56	0.19	0
P62	19-Jul	198.75	30	5	75	90	10	4.48	3.44	5.13	0.38	2
P63	19-Jul	179.67	5	5	90	95	0	1.98	1.44	2.38	0.47	2
P64	23-Jul	99.75	5	35	55	85	5	2.58	1.88	3.00	0.44	0
P65	23-Jul	47.50	0	25	80	95	<1	1.56	1.25	1.88	0.40	0
P66	19-Jul	125.25	0	25	5	90	<1	0.79	0.38	1.13	0.95	2
P67	23-Jul	57.00	5	30	60	80	10	2.46	2.31	2.56	0.10	0
P68	23-Jul	90.75	10	25	80	95	0	3.25	2.94	3.81	0.27	0

Table 10. Vegetation measurements at grassland bird survey points at Homestead National Monument, Nebraska, USA, in 2008. Listed for each Heartland Inventory and Monitoring Network point name (Point) is average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
H01	19-May	102.75	0	5	60	5	30	0.27	0.13	0.38	0.92	0
H02	20-May	152.75	0	40	5	90	0	1.21	0.50	1.75	1.03	≥3
H03	18-May	158.50	0	30	0	95	0	0.85	0.44	1.13	0.80	≥3
H04	19-May	35.75	0	0	80	25	0	1.94	1.25	3.25	1.03	≥3
H05	20-May	145.00	0	65	0	50	0	1.44	0.81	1.81	0.70	≥3
H06	20-May	26.50	0	20	40	30	20	0.48	0.44	0.50	0.13	≥3
H07	20-May	40.75	0	15	40	20	20	0.40	0.25	0.56	0.79	1
H08	20-May	40.00	0	5	1	95	0	1.15	0.88	1.50	0.55	1
H09	20-May	261.00	0	10	40	90	0	0.69	0.06	1.19	1.64	2
H10	21-May	1.00	35	5	75	30	0	1.38	0.38	1.88	1.09	≥3
H11	21-May	36.75	0	30	10	95	0	0.69	0.63	0.81	0.27	1
H12	20-May	158.75	0	5	25	95	0	1.48	0.75	2.75	1.35	1
H13	20-May	1.00	5	40	5	60	0	1.33	0.94	1.63	0.52	2
H14	21-May	10.00	0	35	40	95	0	0.58	0.19	1.00	1.39	≥3
H15	21-May	1.00	25	25	1	95	0	1.58	0.00	4.13	2.61	1
H16	20-May	149.00	0	65	25	45	0	1.85	1.44	2.63	0.64	1
H17	20-May	1.00	25	25	35	65	0	0.75	0.25	1.06	1.08	2
H18	20-May	213.50	10	55	10	90	0	0.65	0.50	0.94	0.68	2
H19	20-May	26.00	5	45	5	40	5	1.35	0.44	2.63	1.62	0
H20	20-May	1.00	10	50	0	75	0	1.02	0.69	1.38	0.67	≥3
H21	20-May	20.25	0	45	5	65	0	1.42	0.81	2.31	1.06	≥3
H22	20-May	1.00	5	1	50	95	0	0.56	0.25	0.75	0.89	1

Table 10. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
H23	20-May	76.50	50	10	20	85	0	0.96	0.69	1.19	0.52	2
H24	20-May	59.25	0	20	15	90	0	1.02	0.56	1.25	0.67	2
H25	20-May	132.50	10	40	10	85	1	1.54	0.75	2.63	1.22	2
H26	20-May	16.00	0	2	35	95	0	0.71	0.38	1.06	0.97	0
H27	20-May	29.75	0	40	70	10	15	0.48	0.31	0.56	0.52	0
H28	20-May	65.25	0	10	45	80	0	0.42	0.06	0.75	1.65	$\geq 3$
H29	20-May	116.25	0	10	25	100	0	1.00	0.63	1.56	0.94	1
H30	20-May	167.50	0	15	10	95	0	0.42	0.25	0.63	0.90	1
H31	20-May	155.25	0	15	55	30	0	1.50	0.56	2.50	1.29	2
H32	20-May	90.50	0	70	5	80	0	1.44	0.94	1.94	0.70	2
H33	19-May	125.75	0	0	55	10	50	1.17	0.25	2.44	1.88	$\geq 3$
H34	20-May	8.50	0	40	1	5	75	4.69	2.94	7.75	1.03	$\geq 3$
H01	21-Jul	61.25	0	10	95	0	0	4.92	4.56	5.13	0.11	0
H02	21-Jul	57.50	0	80	15	20	0	7.04	6.75	7.31	0.08	$\geq 3$
H03	21-Jul	54.25	0	60	75	10	0	6.81	6.25	7.13	0.13	$\geq 3$
H04	21-Jul	27.00	0	10	85	5	0	5.60	5.13	5.88	0.13	$\geq 3$
H05	21-Jul	44.50	0	70	85	0	0	6.23	5.56	6.81	0.20	$\geq 3$
H06	14-Jul	14.50	0	45	85	5	0	5.58	4.25	6.63	0.43	$\geq 3$
H07	14-Jul	29.25	0	45	80	15	5	4.88	4.31	5.19	0.18	1
H08	14-Jul	15.50	0	40	70	55	0	5.46	4.69	6.75	0.38	1
H09	8-Jul	65.25	0	90	30	5	5	3.94	0.00	9.75	2.48	2
H10	14-Jul	1.00	0	70	75	0	0	8.44	5.81	10.31	0.53	$\geq 3$
H11	14-Jul	23.50	0	35	40	65	0	4.60	4.56	4.69	0.03	1
H12	8-Jul	2.25	0	80	55	10	0	4.63	3.75	5.63	0.41	1
H13	8-Jul	1.00	0	90	40	10	0	5.04	3.44	6.00	0.51	2
H14	14-Jul	13.25	0	60	45	5	0	8.73	7.75	9.75	0.23	$\geq 3$

Table 10. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
H15	14-Jul	5.75	0	70	35	5	0	5.10	2.94	6.75	0.75	1
H16	8-Jul	10.00	0	10	100	0	0	5.52	5.25	5.75	0.09	1
H17	8-Jul	1.00	0	100	10	5	0	7.75	7.00	8.88	0.24	2
H18	8-Jul	46.00	0	55	95	10	5	3.40	2.50	4.26	0.52	2
H19	14-Jul	1.00	0	100	0	45	0	5.44	4.19	7.31	0.57	0
H20	14-Jul	25.75	0	55	80	5	0	5.48	4.94	6.00	0.19	$\geq 3$
H21	14-Jul	6.75	5	60	55	0	0	9.56	8.38	10.75	0.25	$\geq 3$
H22	8-Jul	1.00	0	65	80	20	0	7.40	5.44	9.75	0.58	1
H23	8-Jul	41.25	0	65	45	5	0	6.27	5.25	7.31	0.33	2
H24	8-Jul	53.25	0	60	100	5	0	4.08	3.13	5.13	0.49	2
H25	8-Jul	14.75	0	85	50	0	0	4.79	3.25	6.81	0.74	2
H26	14-Jul	15.00	0	55	85	5	0	6.04	5.38	7.00	0.27	0
H27	14-Jul	20.50	0	75	60	0	0	5.10	4.44	5.50	0.21	0
H28	14-Jul	59.25	0	10	95	10	0	3.02	2.63	3.75	0.37	$\geq 3$
H29	8-Jul	73.25	0	15	100	10	0	5.71	3.00	9.38	1.12	1
H30	8-Jul	22.25	0	35	75	20	0	3.88	3.75	3.94	0.05	1
H31	8-Jul	40.50	0	55	85	10	0	3.83	3.50	4.00	0.13	2
H32	8-Jul	4.25	0	75	60	25	10	5.58	5.06	5.88	0.15	2
H33	14-Jul	14.75	0	15	55	40	0	3.08	2.50	4.00	0.49	$\geq 3$
H34	14-Jul	1.00	25	45	0	45	0	6.98	5.25	8.00	0.39	$\geq 3$

Table 11. Vegetation measurements at grassland bird survey points at Tallgrass Prairie National Preserve, Kansas, USA, in 2009. Listed for each Heartland Inventory and Monitoring Network point name (Point) is average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T002	22-May	25.25	60	15	35	10	0	2.65	1.00	4.31	1.25	1
T004	22-May	122.50	0	40	25	40	<1	1.25	0.81	1.94	0.90	1
T005	22-May	60.00	0	15	60	40	5	0.81	0.56	1.25	0.85	1
T009	22-May	587.50	0	20	45	35	5	1.42	0.94	2.06	0.79	1
T010	22-May	152.50	0	30	55	25	<1	0.85	0.56	1.25	0.80	1
T012	22-May	1000.00	0	25	40	20	15	0.46	0.19	0.63	0.95	1
T013	22-May	238.75	0	55	35	15	5	0.77	0.56	1.00	0.57	1
T025	15-May	25.00	0	5	40	10	45	0.15	0.06	0.19	0.86	0
T027	15-May	130.00	0	5	35	5	55	0.08	0.00	0.13	1.50	0
T028	15-May	110.00	0	10	65	15	30	0.02	0.00	0.06	3.00	0
T032	15-May	326.00	0	10	45	15	40	0.02	0.00	0.06	3.00	0
T033	15-May	115.50	0	10	40	5	55	0.04	0.00	0.06	1.50	0
T035	15-May	318.00	0	15	60	10	30	0.02	0.00	0.06	3.00	0
T036	15-May	206.50	0	25	45	35	5	0.15	0.00	0.31	2.14	0
T042	19-May	253.00	0	10	25	65	5	1.08	0.69	1.50	0.75	2
T044	19-May	139.00	0	15	50	35	<1	0.88	0.56	1.31	0.86	2
T047	19-May	350.00	0	15	50	45	0	1.46	0.75	2.06	0.90	2
T049	19-May	20.00	0	40	30	40	0	0.83	0.75	1.00	0.30	2
T053	19-May	600.00	5	20	30	45	5	1.04	0.94	1.25	0.30	2
T055	19-May	301.00	0	10	85	20	0	1.13	1.00	1.31	0.28	2
T058	19-May	300.00	0	5	15	85	5	1.00	0.81	1.13	0.31	2



Table 11. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T060	19-May	375.00	0	50	30	25	0	1.08	0.75	1.31	0.52	2
T087	21-May	800.00	<1	30	30	15	25	0.54	0.25	0.69	0.81	0
T089	21-May	11.00	0	10	60	5	35	0.21	0.06	0.38	1.50	0
T091	21-May	518.00	0	20	50	15	25	0.38	0.31	0.44	0.33	0
T093	21-May	300.00	0	15	45	10	30	0.17	0.06	0.31	1.50	0
T098	20-May	850.00	0	5	65	5	25	0.56	0.44	0.63	0.33	0
T099	20-May	170.00	0	15	65	5	20	0.48	0.44	0.56	0.26	0
T101	20-May	1000.00	0	15	55	5	30	0.48	0.06	0.94	1.83	0
T104	20-May	245.00	0	10	40	10	45	0.29	0.19	0.38	0.64	0
T114	26-May	94.00	0	35	35	40	0	0.63	0.00	1.25	2.00	0
T118	26-May	215.00	0	35	30	10	30	0.38	0.25	0.50	0.67	0
T123	28-May	158.33	0	20	45	15	25	0.54	0.31	0.81	0.92	0
T128	26-May	145.00	0	20	30	50	5	0.29	0.06	0.63	1.93	0
T136	28-May	60.00	0	25	25	30	25	0.46	0.38	0.56	0.41	0
T140	29-May	333.00	0	15	50	15	25	0.35	0.06	0.63	1.59	0
T145	28-May	273.33	0	35	25	5	40	0.48	0.38	0.56	0.39	0
T150	29-May	176.00	0	20	65	5	15	0.50	0.00	1.06	2.13	0
T183	22-May	100.00	0	25	40	20	20	0.94	0.63	1.25	0.67	1
T190	15-May	400.00	0	15	25	25	45	0.10	0.00	0.25	2.40	0
T002	10-Jul	41.50	0	20	70	10	10	3.75	2.56	5.00	0.65	1
T004	9-Jul	182.00	0	5	40	45	20	2.69	2.44	2.94	0.19	1
T005	10-Jul	274.33	0	25	35	35	10	2.71	2.13	3.50	0.51	1
T009	9-Jul	535.00	0	25	45	25	10	3.35	2.38	4.38	0.60	1
T010	9-Jul	152.00	0	25	50	15	15	2.69	2.50	3.00	0.19	1
T012	9-Jul	291.25	0	20	45	30	15	2.21	1.94	2.56	0.28	1

Table 11. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T013	9-Jul	35.00	0	20	40	20	20	2.54	2.00	3.31	0.52	1
T025	8-Jul	24.50	0	5	60	15	25	0.81	0.50	1.00	0.62	0
T027	8-Jul	226.00	0	25	40	10	30	0.56	0.38	0.88	0.89	0
T028	8-Jul	137.00	0	20	55	5	25	0.54	0.25	0.88	1.15	0
T032	8-Jul	131.50	0	15	45	15	25	0.46	0.31	0.63	0.68	0
T033	8-Jul	157.50	0	25	35	10	35	0.94	0.69	1.31	0.67	0
T035	8-Jul	451.00	0	20	55	10	20	0.44	0.19	0.69	1.14	0
T036	8-Jul	97.00	0	10	60	25	5	0.42	0.00	0.81	1.95	0
T042	11-Jul	257.50	0	15	50	35	5	2.50	2.06	2.88	0.33	2
T044	10-Jul	139.00	0	25	40	30	15	1.25	0.31	1.81	1.20	2
T047	11-Jul	37.33	0	40	35	30	5	3.17	2.00	3.81	0.57	2
T049	10-Jul	11.00	0	35	50	25	5	2.56	1.81	2.94	0.44	2
T053	11-Jul	500.00	0	70	25	20	0	2.50	1.69	3.06	0.55	2
T055	10-Jul	56.00	0	20	50	35	<1	2.46	2.19	2.94	0.31	2
T058	11-Jul	180.00	0	10	60	40	<1	2.77	1.81	3.44	0.59	2
T060	10-Jul	271.50	0	30	40	25	10	1.81	1.38	2.63	0.69	2
T087	14-Jul	486.00	0	30	30	20	25	0.98	0.81	1.19	0.38	0
T089	15-Jul	9.00	0	10	55	20	20	0.69	0.63	0.75	0.18	0
T091	14-Jul	408.50	0	10	50	20	25	1.10	1.06	1.13	0.06	0
T093	15-Jul	222.50	0	10	55	20	25	1.81	1.50	2.06	0.31	0
T098	15-Jul	571.67	0	80	25	5	5	1.27	0.94	1.50	0.44	0
T099	15-Jul	390.00	0	15	45	25	20	1.73	1.06	2.19	0.65	0
T101	15-Jul	126.00	0	30	25	35	15	0.58	0.00	0.94	1.61	0
T104	15-Jul	171.33	0	10	40	15	40	0.85	0.69	1.00	0.37	0
T114	13-Jul	25.75	0	55	20	25	5	1.98	1.06	3.13	1.04	0

Table 11. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
T118	13-Jul	228.50	0	20	55	10	25	1.38	1.13	1.63	0.36	0
T123	13-Jul	191.67	0	20	35	5	40	1.40	0.94	1.63	0.49	0
T128	13-Jul	211.33	0	25	40	10	25	1.02	0.81	1.13	0.31	0
T136	14-Jul	53.00	0	10	35	25	35	1.00	0.06	1.81	1.75	0
T140	13-Jul	437.00	0	35	40	10	25	1.98	1.94	2.06	0.06	0
T145	14-Jul	275.50	0	35	30	10	30	0.77	0.38	1.19	1.05	0
T150	13-Jul	184.00	0	70	20	15	<1	2.02	1.81	2.13	0.15	0
T183	10-Jul	113.33	0	25	40	30	10	1.92	1.69	2.19	0.26	1
T190	8-Jul	500.00	0	15	35	5	45	0.52	0.31	0.88	1.08	0

Table 12. Vegetation measurements at grassland bird survey points at Pipestone National Monument, Minnesota, USA, in 2009. Listed for each Heartland Inventory and Monitoring Network point name (Point) is average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P01	2-Jun	60.50	0	15	25	95	<1	1.67	0.63	3.38	1.65	2
P02	2-Jun	89.75	0	5	<1	<1	95	0.19	0.00	0.56	3.00	2
P03	3-Jun	185.50	0	5	30	95	<1	1.10	0.63	1.38	0.68	2
P05	2-Jun	158.00	<1	25	10	95	0	0.71	0.38	1.25	1.24	2
P06	2-Jun	84.75	<1	15	30	80	10	1.98	1.31	2.31	0.51	2
P07	3-Jun	112.25	0	5	70	100	0	1.25	1.13	1.38	0.20	2
P08	3-Jun	134.00	10	10	30	95	<1	1.19	1.13	1.31	0.16	2
P10	10-Jun	113.75	0	5	80	90	5	1.06	0.63	1.38	0.71	1
P11	4-Jun	209.25	0	30	5	10	85	0.56	0.44	0.63	0.33	1
P12	3-Jun	126.00	20	10	35	60	5	2.67	0.00	6.88	2.58	2
P13	3-Jun	150.00	10	10	20	95	<1	1.35	1.19	1.44	0.18	2
P14	3-Jun	100.75	5	10	15	95	5	1.27	0.75	1.63	0.69	2
P15	2-Jun	65.25	0	5	35	100	0	1.33	1.19	1.44	0.19	2
P16	10-Jun	209.00	5	15	30	95	<1	1.58	1.00	1.94	0.59	1
P17	10-Jun	236.50	0	20	5	50	25	1.23	1.19	1.31	0.10	1
P18	4-Jun	210.50	0	0	80	95	0	5.19	2.06	7.81	1.11	1
P19	3-Jun	83.75	20	15	30	90	5	1.46	1.13	1.88	0.51	2
P20	3-Jun	13.25	<1	15	10	85	10	1.60	1.31	1.94	0.39	2
P22	2-Jun	82.50	0	<1	25	95	5	3.75	3.63	3.94	0.08	2
P23	10-Jun	270.50	10	10	15	90	<1	1.73	1.25	2.13	0.51	1
P24	10-Jun	137.25	15	15	40	80	5	1.08	0.63	1.38	0.69	1

Table 12. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P25	4-Jun	11.25	0	0	100	100	0	5.00	3.88	6.75	0.58	1
P26	3-Jun	57.50	10	10	20	95	<1	1.48	0.88	2.13	0.85	2
P29	1-Jun	90.25	0	0	40	35	40	0.48	0.19	0.69	1.04	0
P30	10-Jun	157.25	10	10	25	95	<1	1.50	1.06	1.94	0.58	1
P31	10-Jun	147.25	<1	35	30	85	<1	1.27	1.19	1.38	0.15	1
P32	10-Jun	78.00	15	10	30	90	<1	0.92	0.81	1.06	0.27	1
P35	1-Jun	16.50	<1	10	25	30	50	0.15	0.00	0.31	2.14	0
P36	10-Jun	213.00	5	25	15	95	<1	1.21	1.00	1.44	0.36	1
P37	10-Jun	197.00	5	50	35	25	10	1.17	0.75	1.56	0.70	1
P38	27-May	118.25	15	20	25	65	5	0.46	0.19	0.81	1.36	1
P41	1-Jun	188.25	0	10	20	25	80	0.10	0.00	0.19	1.80	0
P42	10-Jun	26.75	5	15	20	95	4	1.06	0.94	1.25	0.29	1
P43	27-May	195.50	0	15	60	65	<1	1.21	0.75	1.50	0.62	1
P44	4-Jun	33.50	0	<1	15	15	90	2.21	0.00	6.25	2.83	0
P45	30-May	64.25	10	15	15	90	5	1.17	0.44	1.81	1.18	0
P46	30-May	225.50	0	<1	20	50	30	0.21	0.06	0.50	2.10	0
P47	13-Jun	229.75	<1	35	25	95	<1	1.85	1.63	2.25	0.34	1
P48	27-May	88.25	0	10	65	50	5	0.81	0.69	0.94	0.31	1
P49	4-Jun	29.50	0	5	15	45	40	1.19	0.19	3.13	2.47	0
P50	30-May	137.25	0	0	20	10	85	0.29	0.13	0.63	1.71	0
P51	13-Jun	222.75	10	25	15	100	0	1.48	1.44	1.56	0.08	1
P52	28-May	160.75	5	10	50	70	0	1.06	0.88	1.31	0.41	1
P53	28-May	49.75	<1	10	40	45	25	0.06	0.00	0.13	2.00	0
P54	30-May	196.50	0	<1	20	25	85	0.52	0.13	0.81	1.32	0
P55	13-Jun	172.50	5	10	75	95	0	2.33	2.13	2.56	0.19	1

Table 12. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P56	13-Jun	2.00	0	10	35	100	0	2.77	1.63	4.94	1.20	1
P57	28-May	78.50	10	10	5	5	90	0.06	0.00	0.19	3.00	0
P59	29-May	121.25	<1	10	50	15	55	0.50	0.00	0.75	1.50	0
P60	13-Jun	30.00	5	10	40	95	0	1.85	1.75	1.94	0.10	1
P61	11-Jun	77.75	0	10	25	100	0	1.90	1.31	2.38	0.56	1
P62	4-Jun	218.75	5	5	10	10	85	0.15	0.13	0.19	0.43	0
P63	29-May	231.75	5	<1	20	10	80	0.27	0.00	0.69	2.54	0
P64	11-Jun	176.00	5	15	30	100	0	2.23	1.69	3.25	0.70	1
P65	11-Jun	123.50	0	10	20	100	0	1.77	1.38	2.25	0.49	1
P66	29-May	120.50	0	20	5	5	90	0.67	0.06	1.25	1.78	0
P67	11-Jun	203.00	5	5	25	100	0	1.94	1.38	2.69	0.68	1
P68	11-Jun	125.75	5	60	30	100	0	1.92	1.50	2.19	0.36	1
P01	21-Jul	64.75	0	30	15	80	20	2.83	1.88	3.44	0.55	2
P02	16-Jul	70.75	15	25	15	75	25	1.29	0.50	2.19	1.31	2
P03	21-Jul	68.75	0	10	35	100	0	2.46	1.63	3.88	0.92	2
P05	21-Jul	133.50	5	35	5	100	0	1.48	1.25	1.69	0.30	2
P06	16-Jul	77.00	10	20	20	100	0	2.81	2.13	3.44	0.47	2
P07	21-Jul	129.75	5	10	30	95	5	2.56	2.44	2.81	0.15	2
P08	21-Jul	142.50	5	55	10	100	0	2.40	1.88	3.25	0.57	2
P10	26-Jul	110.25	0	5	45	95	5	2.85	2.56	3.38	0.28	1
P11	26-Jul	21.25	<1	5	40	100	0	1.29	0.75	1.63	0.68	1
P12	19-Jul	99.25	25	20	30	95	<1	3.06	0.00	6.38	2.08	2
P13	20-Jul	92.00	5	15	30	100	0	3.13	2.38	3.56	0.38	2
P14	21-Jul	74.25	0	10	60	100	0	2.17	1.63	2.81	0.55	2
P15	16-Jul	2.25	0	<1	0	<1	100	2.31	0.63	3.88	1.41	2

Table 12. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P16	26-Jul	38.25	0	25	30	100	0	3.06	2.31	3.56	0.41	1
P17	26-Jul	137.75	5	20	<1	85	15	2.42	1.63	3.38	0.72	1
P18	26-Jul	0.00	20	0	95	35	35	11.90	8.19	14.06	0.49	1
P19	19-Jul	67.00	15	25	70	90	10	1.79	1.31	2.13	0.45	2
P20	20-Jul	18.75	0	30	25	70	30	3.02	2.31	3.81	0.50	2
P22	16-Jul	64.00	0	0	30	95	<1	3.67	2.81	5.00	0.60	2
P23	26-Jul	117.25	0	20	50	100	0	3.10	2.38	3.81	0.46	1
P24	26-Jul	83.50	5	15	80	100	0	2.90	2.44	3.13	0.24	1
P25	26-Jul	11.50	0	5	100	90	60	9.31	6.56	14.19	0.82	1
P26	19-Jul	49.75	20	20	50	100	0	2.15	1.88	2.63	0.35	2
P29	17-Jul	45.75	0	<1	35	10	90	3.81	2.94	4.38	0.38	0
P30	24-Jul	37.50	10	15	15	60	40	3.50	3.13	4.06	0.27	1
P31	24-Jul	119.25	<1	15	20	65	35	2.58	2.13	3.19	0.41	1
P32	24-Jul	44.75	15	10	10	95	5	2.48	2.25	2.75	0.20	1
P35	17-Jul	37.50	15	10	5	15	85	1.63	0.75	2.50	1.08	0
P36	24-Jul	70.25	0	20	20	100	0	3.31	2.69	4.25	0.47	1
P37	24-Jul	114.25	0	20	5	70	30	2.69	2.50	2.94	0.16	1
P38	24-Jul	171.50	10	40	5	95	5	1.56	1.06	2.06	0.64	1
P41	17-Jul	113.75	5	15	10	5	95	1.10	0.69	1.38	0.62	0
P42	24-Jul	38.75	5	5	15	100	0	2.73	2.06	3.88	0.66	1
P43	24-Jul	17.00	0	15	10	100	0	3.00	1.94	4.25	0.77	1
P44	21-Jul	25.75	0	10	10	10	90	2.73	1.31	4.94	1.33	0
P45	17-Jul	42.50	5	30	5	100	0	1.69	1.13	2.38	0.74	0
P46	17-Jul	221.75	5	10	35	15	85	1.31	1.06	1.50	0.33	0
P47	23-Jul	64.50	0	30	10	100	0	3.98	3.69	4.38	0.17	1

Table 12. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
P48	23-Jul	83.25	<1	<1	50	90	10	1.60	1.13	2.13	0.62	1
P49	21-Jul	16.00	5	15	60	10	90	1.77	0.00	3.81	2.15	0
P50	17-Jul	152.75	0	0	50	10	90	1.23	0.88	1.50	0.51	0
P51	23-Jul	185.75	25	30	20	100	0	3.96	2.88	4.56	0.43	1
P52	23-Jul	240.75	0	20	25	100	0	2.85	2.75	3.00	0.09	1
P53	21-Jul	72.00	5	5	55	5	95	1.71	1.19	2.31	0.66	0
P54	17-Jul	162.50	0	5	100	5	95	5.23	2.56	6.69	0.79	0
P55	23-Jul	52.00	<1	20	40	100	0	5.23	4.75	6.13	0.26	1
P56	23-Jul	2.50	<1	10	45	100	0	9.44	3.69	15.94	1.30	1
P57	22-Jul	107.00	20	50	15	10	90	2.79	1.56	4.13	0.92	0
P59	17-Jul	210.75	0	50	10	50	50	1.42	0.63	2.06	1.01	0
P60	23-Jul	71.75	0	20	15	100	0	3.38	3.13	3.75	0.19	1
P61	23-Jul	127.50	0	10	70	100	0	3.29	3.13	3.50	0.11	1
P62	22-Jul	121.25	10	30	40	<1	100	1.67	1.25	2.44	0.71	0
P63	17-Jul	242.00	10	50	30	15	85	0.94	0.00	1.81	1.93	0
P64	22-Jul	110.00	5	85	20	95	5	3.42	2.94	3.81	0.26	1
P65	22-Jul	143.75	0	5	15	100	0	2.73	1.44	4.00	0.94	1
P66	17-Jul	170.75	0	5	10	20	90	0.73	0.19	1.38	1.63	0
P67	22-Jul	55.00	0	5	70	100	0	3.27	2.75	3.88	0.34	1
P68	22-Jul	68.50	10	15	85	100	0	5.46	4.25	6.13	0.34	1



Table 13. Vegetation measurements at grassland bird survey points at Homestead National Monument, Minnesota, USA, in 2009. Listed for each Heartland Inventory and Monitoring Network point name (Point) is average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
H01	19-May	63.75	0	5	75	90	0	0.73	0.56	0.94	0.51	1
H02	26-May	83.50	0	5	50	95	0	2.75	1.63	3.44	0.66	≥3
H03	19-May	117.00	0	25	15	95	0	2.29	1.69	2.81	0.49	≥3
H04	26-May	69.50	0	1	80	100	0	3.75	1.81	4.94	0.83	≥3
H05	25-May	126.25	0	70	0	95	1	4.02	2.56	5.50	0.73	≥3
H06	25-May	48.75	25	5	50	50	0	4.83	1.38	10.13	1.81	≥3
H07	26-May	141.25	0	5	30	99	1	0.73	0.38	0.94	0.77	0
H08	29-May	154.00	1	10	25	95	5	0.79	0.63	1.06	0.55	0
H09	29-May	156.25	1	30	80	85	5	4.83	0.63	12.75	2.51	1
H10	29-May	139.75	<1	85	30	95	1	1.69	1.06	2.00	0.56	≥3
H11	26-May	213.00	0	10	20	95	5	0.23	0.06	0.44	1.64	0
H12	29-May	211.75	0	10	15	55	20	0.98	0.69	1.13	0.45	0
H13	29-May	195.75	<1	10	35	95	1	0.75	0.31	1.06	1.00	0
H14	28-May	53.25	1	50	60	95	0	2.13	0.63	4.13	1.65	≥3
H15	28-May	126.50	5	20	10	95	5	0.58	0.38	0.94	0.96	0
H16	28-May	170.50	0	10	25	95	<1	0.71	0.50	0.81	0.44	0
H17	28-May	132.00	1	10	75	50	10	0.94	0.56	1.31	0.80	0
H18	27-May	119.25	1	10	55	90	10	0.17	0.06	0.25	1.13	0
H19	28-May	35.50	5	95	1	90	5	4.71	3.25	6.81	0.76	1
H20	28-May	48.50	5	60	20	95	1	2.42	1.38	3.00	0.67	≥3
H21	28-May	6.25	1	15	50	90	0	3.81	3.06	5.31	0.59	≥3

Table 13. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
H22	28-May	121.00	1	5	10	95	5	0.60	0.44	0.75	0.52	0
H23	28-May	235.25	1	10	70	95	1	0.79	0.63	0.88	0.32	0
H24	28-May	204.00	0	30	45	65	10	0.58	0.25	0.94	1.18	0
H25	27-May	147.75	0	10	50	95	<1	0.50	0.31	0.69	0.75	0
H26	28-May	23.00	1	50	40	95	1	2.77	0.69	4.25	1.29	1
H27	28-May	97.75	0	25	40	95	1	1.94	1.75	2.19	0.23	1
H28	28-May	70.25	0	5	65	100	0	2.42	2.19	2.69	0.21	≥3
H29	28-May	167.25	0	1	70	95	5	0.58	0.44	0.81	0.64	0
H30	28-May	112.75	0	15	60	95	1	0.85	0.75	1.06	0.37	0
H31	27-May	162.75	5	25	30	95	1	0.42	0.19	0.56	0.90	0
H32	27-May	149.50	1	20	10	95	5	0.33	0.06	0.75	2.06	0
H33	25-May	22.50	0	5	90	55	0	2.67	2.13	3.06	0.35	≥3
H34	28-May	31.25	1	75	35	95	0	3.98	2.75	4.88	0.53	≥3
H01	17-Jul	86.50	0	5	85	95	1	1.56	1.00	2.13	0.72	1
H02	17-Jul	41.50	0	20	65	95	5	6.29	4.13	8.69	0.73	≥3
H03	17-Jul	92.25	0	20	90	95	1	7.73	5.06	9.94	0.63	≥3
H04	13-Jul	42.50	0	1	95	95	1	3.44	1.50	5.19	1.07	≥3
H05	17-Jul	79.50	1	90	1	95	1	9.58	9.06	10.06	0.10	≥3
H06	13-Jul	56.50	70	5	85	95	1	8.98	5.19	14.94	1.09	≥3
H07	21-Jul	143.75	0	10	95	90	10	7.29	6.44	8.44	0.27	0
H08	21-Jul	71.75	0	15	95	95	1	7.73	6.88	9.25	0.31	0
H09	21-Jul	32.50	0	25	40	95	1	6.96	1.25	11.44	1.46	1
H10	21-Jul	42.00	0	80	80	95	1	6.21	5.63	6.88	0.20	≥3
H11	21-Jul	101.75	0	65	70	95	1	6.75	6.63	7.00	0.06	0
H12	21-Jul	29.50	0	70	80	95	1	8.35	7.44	10.13	0.32	0

Table 13. continued.

Point	Date	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
H13	21-Jul	86.75	0	80	40	95	1	6.50	5.38	7.19	0.28	0
H14	21-Jul	34.75	0	60	50	95	1	5.83	4.00	8.31	0.74	$\geq 3$
H15	21-Jul	29.75	0	75	50	95	1	12.52	6.94	16.50	0.76	0
H16	21-Jul	22.75	0	55	55	95	1	8.27	6.25	12.19	0.72	0
H17	21-Jul	9.25	5	75	50	95	1	12.02	9.81	15.81	0.50	0
H18	21-Jul	93.00	0	20	50	90	5	3.73	2.38	5.00	0.70	0
H19	14-Jul	42.50	1	90	0	30	65	11.85	11.13	13.19	0.17	1
H20	14-Jul	35.00	1	30	90	95	5	6.02	5.50	6.81	0.22	$\geq 3$
H21	14-Jul	42.75	<1	40	40	95	1	7.79	6.25	9.38	0.40	$\geq 3$
H22	21-Jul	8.00	1	60	80	95	1	9.19	6.44	10.63	0.46	0
H23	21-Jul	102.50	0	45	70	95	1	6.46	5.50	7.75	0.35	0
H24	21-Jul	77.50	0	85	35	95	1	4.77	4.19	5.25	0.22	0
H25	14-Jul	44.75	0	65	15	35	60	5.46	4.94	6.44	0.27	0
H26	14-Jul	42.00	0	50	75	95	1	8.31	4.25	14.81	1.27	1
H27	14-Jul	56.00	0	30	95	95	1	4.79	4.69	4.88	0.04	1
H28	14-Jul	59.50	0	5	95	95	1	4.96	4.31	6.06	0.35	$\geq 3$
H29	14-Jul	95.50	0	15	85	50	50	7.10	3.88	12.19	1.17	0
H30	21-Jul	43.25	0	35	90	95	1	5.79	5.19	6.31	0.19	0
H31	21-Jul	69.75	1	60	60	95	1	3.33	1.63	4.38	0.83	0
H32	14-Jul	86.25	1	45	45	85	10	6.42	5.56	8.06	0.39	0
H33	14-Jul	22.75	0	10	95	95	1	3.81	2.44	4.63	0.57	$\geq 3$
H34	14-Jul	6.25	15	65	50	90	5	5.40	3.19	9.25	1.12	$\geq 3$

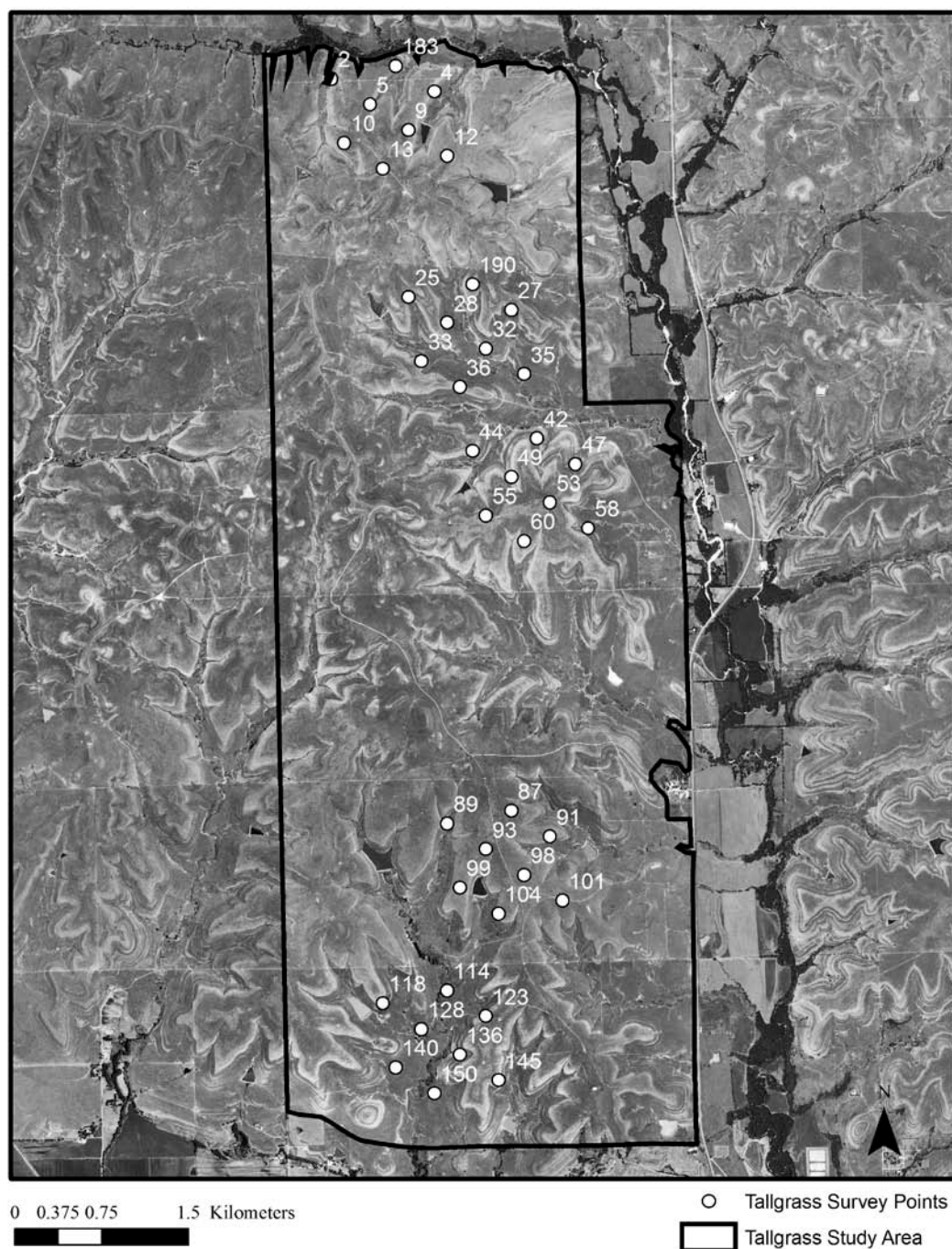


Figure 1. Location of 40 Heartland Inventory and Monitoring Network avian survey points at Tallgrass Prairie National Preserve, KS, USA, in 2008 and 2009.



Figure 2. Location of 58 Heartland Inventory and Monitoring Network avian survey points at Pipestone National Monument, MN, USA, in 2008 and 2009.

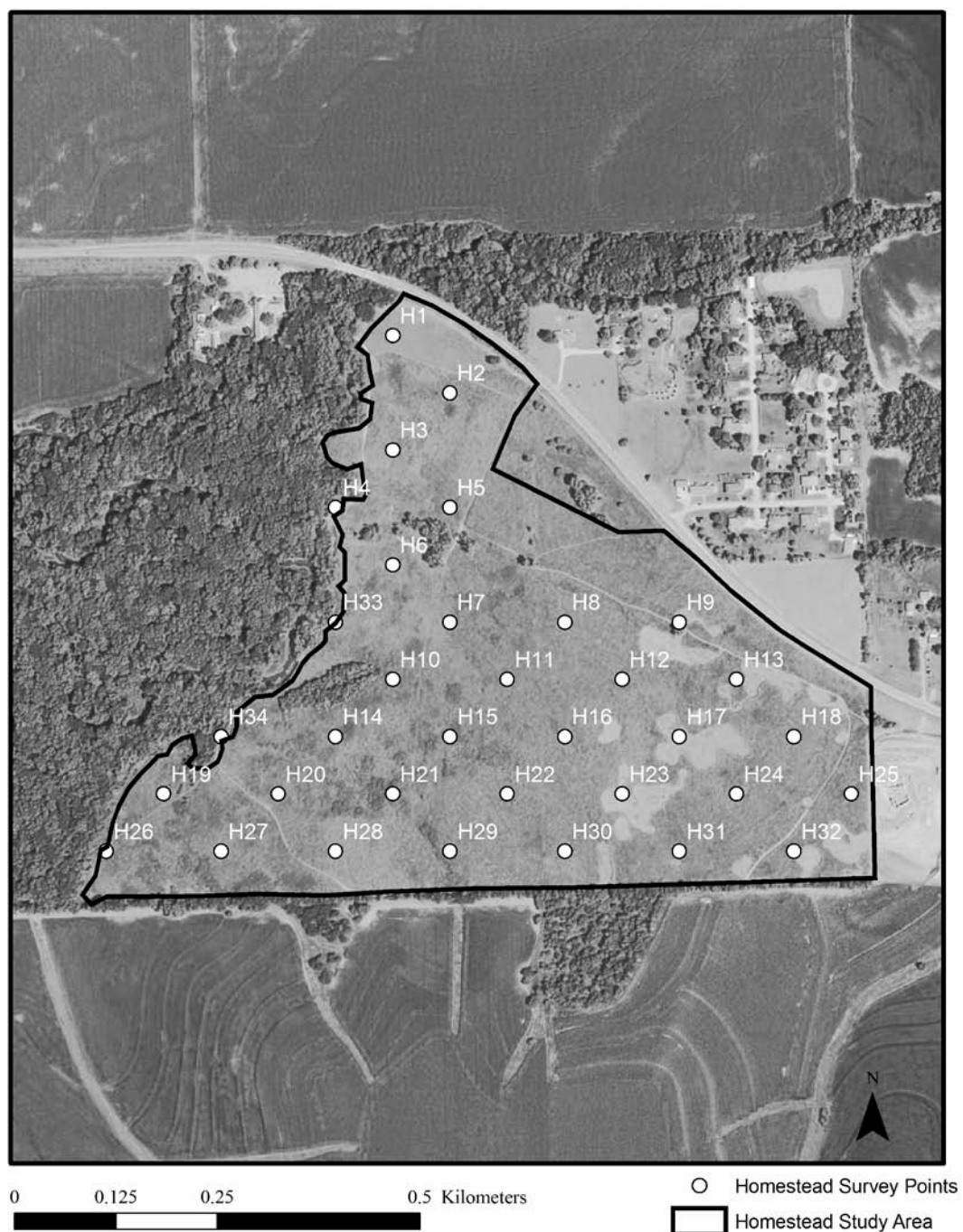


Figure 3. Location of 34 Heartland Inventory and Monitoring Network avian survey points at Homestead National Monument, NE, USA, in 2008 and 2009.

## Appendix B: SUPPLEMENTAL NEST MONITORING TABLES AND FIGURES

Table 1. Nesting survival and success data for birds at Tallgrass Prairie National Preserve, Kansas, Pipestone National Monument, Minnesota, and Homestead National Monument, Nebraska, USA, 2008.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Failure Reason
Brown Thrasher								
Homestead	BRTH4008H	684304	4461704	29-May-08	23-Jun-08	23-Jun-08	success	
Clay-colored Sparrow								
Pipestone	CCSP6017P	714747	4877185	17-Jun-08	17-Jun-08	18-Jun-08	fail	parasitism
Pipestone	CCSP6018P	714703	4877416	18-Jun-08	18-Jun-08	30-Jun-08	unknown	abandoned
Common Nighthawk								
Tallgrass	CONI1008T	711364	4259630	10-Jun-08	22-Jul-08	25-Jul-08	fail	depredated
Tallgrass	CONI2008T	711474	4254850	18-Jun-08	17-Jul-08	17-Jul-08	success	
Tallgrass	CONI2013T	711364	4259630	30-Jun-08	14-Jul-08	17-Jul-08	fail	depredated
Tallgrass	CONI2020T	710771	4260250	10-Jul-08	23-Jul-08	30-Jul-08	fail	depredated
Common Yellowthroat								
Pipestone	COYE6022P	714914	4876866	03-Jul-08	03-Jul-08	08-Jul-08	fail	depredated
Dickcissel								
Tallgrass	DICK1019T	710891	4254515	23-Jun-08	25-Jun-08	28-Jun-08	fail	depredated
Tallgrass	DICK1020T	711747	4259095	24-Jun-08	25-Jun-08	30-Jun-08	fail	depredated
Tallgrass	DICK1021T	711205	4259896	03-Jul-08	03-Jul-08	07-Jul-08	fail	abandoned
Tallgrass	DICK1022T	710667	4260130	07-Jul-08	07-Jul-08	10-Jul-08	fail	depredated
Tallgrass	DICK1024T	711091	4259859	10-Jul-08	15-Jul-08	18-Jul-08	fail	depredated
Tallgrass	DICK1026T	711312	4260274	11-Jul-08	11-Jul-08	15-Jul-08	fail	depredated
Tallgrass	DICK1027T	711593	4260437	15-Jul-08	19-Jul-08	23-Jul-08	fail	nest destruction
Tallgrass	DICK1031T	711531	4259008	18-Jul-08	18-Jul-08	22-Jul-08	fail	depredated
Tallgrass	DICK1032T	711604	4260389	19-Jul-08	26-Jul-08	30-Jul-08	fail	depredated

Table 1. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Failure Reason
Dickcissel, cont.								
Tallgrass	DICK1033T	711605	4260352	19-Jul-08	19-Jul-08	23-Jul-08	fail	abandoned
Tallgrass	DICK2007T	711590	4256199	17-Jun-08	17-Jun-08	20-Jun-08	fail	depredated
Tallgrass	DICK2009T	710938	4254937	20-Jun-08	25-Jun-08	28-Jun-08	fail	depredated
Tallgrass	DICK2010T	710795	4254949	23-Jun-08	25-Jun-08	28-Jun-08	fail	depredated
Tallgrass	DICK2012T	711474	4260260	26-Jun-08	01-Jul-08	03-Jul-08	fail	depredated
Tallgrass	DICK2016T	710458	4261254	27-Jun-08	07-Jul-08	10-Jul-08	fail	depredated
Tallgrass	DICK2018T	711785	4259388	09-Jul-08	15-Jul-08	18-Jul-08	fail	depredated
Tallgrass	DICK2021T	711670	4260160	11-Jul-08	30-Jul-08	30-Jul-08	success	
Tallgrass	DICK2022T	711592	4260830	11-Jul-08	11-Jul-08	15-Jul-08	fail	depredated
Tallgrass	DICK2023T	711460	4259006	17-Jul-08	17-Jul-08	22-Jul-08	fail	depredated
Homestead	DICK3016H	684677	4461808	09-Jun-08	10-Jun-08	13-Jun-08	fail	abandoned
Homestead	DICK3018H	684568	4461761	17-Jun-08	23-Jun-08	25-Jun-08	fail	depredated
Homestead	DICK3019H	684442	4462008	27-Jun-08	07-Jul-08	08-Jul-08	success	
Homestead	DICK3020H	684230	4462160	03-Jul-08	15-Jul-08	18-Jul-08	fail	storm
Homestead	DICK3021H	684436	4462009	07-Jul-08	24-Jul-08	24-Jul-08	success	
Homestead	DICK3022H	684180	4461966	08-Jul-08	11-Jul-08	15-Jul-08	fail	depredated
Homestead	DICK4013H	684564	4461857	23-Jun-08	03-Jul-08	07-Jul-08	fail	depredated
Homestead	DICK4014H	684557	4461938	23-Jun-08	30-Jun-08	03-Jul-08	fail	depredated
Homestead	DICK4015H	684505	4461874	25-Jun-08	03-Jul-08	07-Jul-08	success	
Homestead	DICK4016H	684390	4461998	01-Jul-08	15-Jul-08	15-Jul-08	success	
Homestead	DICK4017H	684354	4462000	01-Jul-08	18-Jul-08	18-Jul-08	success	
Homestead	DICK4018H	684125	4462018	14-Jul-08	24-Jul-08	24-Jul-08	success	
Eastern Meadowlark								
Tallgrass	EAME1001T	711538	4256584	22-May-08	27-May-08	29-May-08	fail	depredated



Table 1. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Failure Reason
Eastern Meadowlark, cont.								
Tallgrass	EAME1002T	711109	4255029	28-May-08	10-Jun-08	10-Jun-08	success	
Tallgrass	EAME1005T	712381	4259356	30-May-08	03-Jun-08	03-Jun-08	fail	unknown
Tallgrass	EAME1011T	710892	4254923	11-Jun-08	13-Jun-08	16-Jun-08	fail	depredated
Tallgrass	EAME1013T	710933	4260587	12-Jun-08	24-Jun-08	24-Jun-08	success	
Tallgrass	EAME1029T	711864	4255801	17-Jul-08	31-Jul-08	31-Jul-08	success	
Tallgrass	EAME2005T	712107	4259079	13-Jun-08	01-Jul-08	01-Jul-08	success	
Tallgrass	EAME2011T	711337	4259630	25-Jun-08	25-Jun-08	30-Jun-08	fail	depredated
Tallgrass	EAME2025T	711738	4259027	23-Jul-08	26-Jul-08	30-Jul-08	fail	abandoned
Gray Catbird								
Homestead	GRCA3014H	684189	4461769	29-May-08	29-May-08	02-Jun-08	fail	nest destruction
Grasshopper Sparrow								
Tallgrass	GRSP1003T	710180	4261335	29-May-08	03-Jun-08	06-Jun-08	fail	depredated
Tallgrass	GRSP1009T	712337	4259109	10-Jun-08	21-Jun-08	21-Jun-08	success	
Tallgrass	GRSP1012T	711622	4261020	12-Jun-08	23-Jun-08	23-Jun-08	success	
Tallgrass	GRSP1014T	711698	4259111	12-Jun-08	13-Jun-08	16-Jun-08	fail	depredated
Tallgrass	GRSP1028T	712079	4259594	16-Jul-08	31-Jul-08	31-Jul-08	success	
Tallgrass	GRSP1034T	710679	4260367	19-Jul-08	31-Jul-08	31-Jul-08	success	
Tallgrass	GRSP1035T	711144	4260269	24-Jul-08	30-Jul-08	30-Jul-08	success	
Tallgrass	GRSP1036T	711305	4261052	24-Jul-08	31-Jul-08	31-Jul-08	success	
Tallgrass	GRSP2002T	710870	4254860	03-Jun-08	13-Jun-08	16-Jun-08	fail	depredated
Tallgrass	GRSP2024T	711595	4260516	16-Jul-08	16-Jul-08	19-Jul-08	fail	nest destruction

Table 1. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Failure Reason
Henslow's Sparrow								
Tallgrass	HESP1018T	710693	4254723	23-Jun-08	25-Jun-08	25-Jun-08	unknown	
Tallgrass	HESP1025T	710880	4260478	11-Jul-08	16-Jul-08	23-Jul-08	Fail	depredated
Tallgrass	HESP2014T	711830	4259211	08-Jul-08	11-Jul-08	18-Jul-08	unknown	
Lark Sparrow								
Tallgrass	LASP1006T	710164	4262837	05-Jun-08	12-Jun-08	16-Jun-08	fail	depredated
Mourning Dove								
Tallgrass	MODO1017T	711327	4259635	22-Jun-08	01-Jul-08	03-Jul-08	fail	depredated
Tallgrass	MODO2004T	710909	4254883	06-Jun-08	09-Jun-08	11-Jun-08	fail	depredated
Tallgrass	MODO2015T	711702	4255301	08-Jul-08	11-Jul-08	15-Jul-08	fail	depredated
Homestead	MODO4009H	684392	4461811	29-May-08	29-May-08	02-Jun-08	fail	abandoned
Ring-necked Pheasant								
Pipestone	RNEP6015P	714900	4876870	15-Jun-08	15-Jun-08	25-Jun-08	success	
Red-winged Blackbird								
Homestead	RWBL3001H	684114	4462176	15-May-08	08-Jun-08	08-Jun-08	success	
Homestead	RWBL3003H	684227	4461955	15-May-08	23-May-08	02-Jun-08	fail	abandoned
Homestead	RWBL3004H	684148	4462245	16-May-08	13-Jun-08	13-Jun-08	success	
Homestead	RWBL3006H	684111	4462187	19-May-08	31-May-08	04-Jun-08	fail	storm
Homestead	RWBL3007H	684135	4462224	19-May-08	10-Jun-08	10-Jun-08	success	
Homestead	RWBL3008H	684115	4462018	21-May-08	21-May-08	23-May-08	fail	storm
Homestead	RWBL3009H	684206	4461814	21-May-08	23-May-08	27-May-08	fail	storm
Homestead	RWBL3010H	684269	4462005	21-May-08	21-May-08	23-May-08	fail	depredated
Homestead	RWBL3011H	684268	4462008	21-May-08	23-May-08	23-May-08	fail	depredated
Homestead	RWBL3012H	684623	4461679	21-May-08	27-May-08	31-May-08	fail	abandoned
Homestead	RWBL3013H	684382	4461644	21-May-08	04-Jun-08	06-Jun-08	fail	abandoned

Table 1. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Failure Reason
Red-winged Blackbird, cont.								
Homestead	RWBL3017H	684113	4462216	16-Jun-08	16-Jun-08	20-Jun-08	fail	depredated
Homestead	RWBL4002H	684317	4461964	15-May-08	19-May-08	02-Jun-08	fail	abandoned
Homestead	RWBL4006H	684398	4461915	20-May-08	27-May-08	31-May-08	fail	
Homestead	RWBL4007H	684148	4462039	21-May-08	21-May-08	23-May-08	fail	depredated
Homestead	RWBL4010H	684124	4462211	31-May-08	17-Jun-08	17-Jun-08	success	
Homestead	RWBL4011H	684259	4462024	31-May-08	31-May-08	04-Jun-08	fail	storm
Pipestone	RWBL6004P	714947	4876935	02-Jun-08	17-Jun-08	17-Jun-08	success	
Pipestone	RWBL6007P	714790	4877325	07-Jun-08	23-Jun-08	23-Jun-08	unknown	
Pipestone	RWBL6008P	714551	4876967	07-Jun-08	10-Jun-08	23-Jun-08	fail	female death
Pipestone	RWBL6009P	714288	4877202	08-Jun-08	08-Jun-08	15-Jun-08	fail	depredated
Pipestone	RWBL6014P	714875	4876934	15-Jun-08	21-Jun-08	23-Jun-08	fail	depredated
Upland Sandpiper								
Tallgrass	UPSA2006T	711487	4256652	17-Jun-08	25-Jun-08	28-Jun-08	fail	depredated
Tallgrass	UPSA2017T	711650	4259174	08-Jul-08	08-Jul-08	11-Jul-08	fail	depredated
Eastern Meadowlark								
Tallgrass	WEME2001T	711514	4256478	27-May-08	03-Jun-08	12-Jun-08	fail	abandoned
Wild Turkey								
Homestead	WITU4001H	684112	4462142	14-May-08	26-May-08	26-May-08	success	
Pipestone	WITU6001P	714431	4876809	22-May-08	12-Jun-08	12-Jun-08	success	

Table 2. Nesting survival and success data for birds at Tallgrass Prairie National Preserve, Kansas, Pipestone National Monument, Minnesota, and Homestead National Monument, Nebraska, USA, in 2009.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Final Result
American Goldfinch								
Pipestone	AMGO6008P	714419	4876794	20-Jul-09	01-Aug-09	01-Aug-09	success	
Clay-colored Sparrow								
Pipestone	CCSP5001P	714377	4877207	04-Jun-09	18-Jun-09	22-Jun-09	fail	depredated
Pipestone	CCSP5002P	714614	4877124	19-Jun-09	19-Jun-09	22-Jun-09	fail	depredated
Pipestone	CCSP5004P	714579	4877138	01-Jul-09	10-Jul-09	13-Jul-09	fail	depredated
Pipestone	CCSP5009P	714739	4877237	16-Jul-09	30-Jul-09	30-Jul-09	success	
Pipestone	CCSP6003P	714480	4877167	01-Jul-09	04-Jul-09	07-Jul-09	fail	depredated
Pipestone	CCSP6012P	714214	4876932	24-Jul-09	01-Aug-09	01-Aug-09	success	
Pipestone	CCSP6014P	714413	4876777	30-Jul-09	01-Aug-09	01-Aug-09	success	
Common Nighthawk								
Tallgrass	CONI2005T	711529	4254338	28-May-09	11-Jun-09	15-Jun-09	fail	depredated
Tallgrass	CONI2013T	711951	4256377	24-Jun-09	11-Jul-09	14-Jul-09	fail	abandoned
Tallgrass	CONI2018T	711232	4262390	30-Jun-09	17-Jul-09	17-Jul-09	success	
Dickcissel								
Homestead	DICK3004H	684030	4461726	15-Jun-09	03-Jul-09	03-Jul-09	success	
Homestead	DICK3005H	684255	4462230	16-Jun-09	29-Jun-09	29-Jun-09	success	
Homestead	DICK3006H	684148	4462272	22-Jun-09	03-Jul-09	06-Jul-09	fail	abandoned
Homestead	DICK3010H	684258	4462161	07-Jul-09	07-Jul-09	10-Jul-09	fail	depredated
Homestead	DICK4008H	684234	4462148	04-Jun-09	15-Jun-09	19-Jul-09	fail	depredated
Homestead	DICK4012H	684424	4461997	22-Jun-09	07-Jul-09	07-Jul-09	success	
Homestead	DICK4013H	684509	4461969	30-Jun-09	10-Jul-09	10-Jul-09	success	
Homestead	DICK4014H	684131	4461735	03-Jul-09	10-Jul-09	13-Jul-09	fail	depredated
Homestead	DICK4015H	684462	4461708	07-Jul-09	21-Jul-09	23-Jul-09	fail	depredated

Table 2. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Final Result
Dickcissel, cont.								
Homestead	DICK4016H	684126	4461724	14-Jul-09	14-Jul-09	17-Jul-09	fail	depredated
Homestead	DICK4017H	684724	4461826	15-Jul-09	15-Jul-09	15-Jul-09	success	
Homestead	DICK7010H	684436	4461987	04-Jun-09	08-Jun-09	11-Jun-09	fail	depredated
Tallgrass	DICK1013T	711063	4262653	11-Jun-09	25-Jun-09	28-Jun-09	fail	depredated
Tallgrass	DICK1015T	711325	4260170	13-Jun-09	13-Jun-09	16-Jun-09	fail	depredated
Tallgrass	DICK1019T	711146	4262710	30-Jun-09	07-Jul-09	07-Jul-09	success	
Tallgrass	DICK1023T	710989	4260450	08-Jul-09	10-Jul-09	13-Jul-09	fail	depredated
Tallgrass	DICK1025T	711089	4262403	13-Jul-09	21-Jul-09	21-Jul-09	success	
Tallgrass	DICK2007T	711926	4260008	13-Jun-09	22-Jun-09	25-Jun-09	fail	depredated
Tallgrass	DICK2015T	711293	4260053	26-Jun-09	03-Jul-09	03-Jul-09	success	
Tallgrass	DICK2016T	711252	4262893	30-Jun-09	03-Jul-09	06-Jul-09	fail	depredated
Tallgrass	DICK2017T	711001	4262614	30-Jun-09	09-Jul-09	13-Jul-09	fail	depredated
Tallgrass	DICK2019T	711205	4260201	01-Jul-09	01-Jul-09	03-Jul-09	fail	abandoned
Tallgrass	DICK2021T	710998	4261074	08-Jul-09	17-Jul-09	17-Jul-09	success	
Tallgrass	DICK2025T	710985	4254122	13-Jul-09	21-Jul-09	21-Jul-09	success	
Eastern Kingbird								
Pipestone	EAKI6007P	714318	4876983	13-Jul-09	22-Jul-09	22-Jul-09	success	
Eastern Meadowlark								
Tallgrass	EAME1001T	711116	4260190	14-May-09	14-May-09	18-May-09	fail	depredated
Tallgrass	EAME1002T	711263	4260142	14-May-09	14-May-09	18-May-09	fail	depredated
Tallgrass	EAME1006T	711357	4259746	19-May-09	04-Jun-09	04-Jun-09	success	
Tallgrass	EAME1007T	711080	4262664	22-May-09	24-May-09	27-May-09	fail	depredated
Tallgrass	EAME1012T	711391	4259519	03-Jun-09	09-Jun-09	09-Jun-09	success	
Tallgrass	EAME1014T	711603	4255970	12-Jun-09	13-Jun-09	13-Jun-09	success	

Table 2. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Final Result
Eastern Meadowlark, cont.								
Tallgrass	EAME1018T	711758	4255969	26-Jun-09	26-Jun-09	28-Jun-09	fail	abandoned
Tallgrass	EAME1022T	711170	4262606	03-Jul-09	13-Jul-09	17-Jul-09	fail	infertile
Tallgrass	EAME2010T	711341	4255799	12-Jun-09	12-Jun-09	15-Jun-09	fail	abandoned
Field Sparrow								
Pipestone	FISP5003P	714720	4877249	25-Jun-09	02-Jul-09	02-Jul-09	success	
Pipestone	FISP5010P	714749	4877170	19-Jul-09	22-Jul-09	26-Jul-09	fail	depredated
Pipestone	FISP6001P	714371	4877198	29-May-09	29-May-09	01-Jun-09	fail	abandoned
Pipestone	FISP6013P	714909	4876897	26-Jul-09	01-Aug-09	01-Aug-09	success	
Grasshopper Sparrow								
Tallgrass	GRSP1004T	710273	4262401	18-May-09	18-May-09	21-May-09	fail	abandoned
Tallgrass	GRSP1026T	711757	4255971	15-Jul-09	21-Jul-09	21-Jul-09	success	
Tallgrass	GRSP2003T	710436	4262676	22-May-09	27-May-09	27-May-09	fail	unknown
Tallgrass	GRSP2004T	711838	4259001	28-May-09	02-Jun-09	08-Jun-09	fail	depredated
Tallgrass	GRSP2008T	710789	4259135	10-Jun-09	13-Jun-09	16-Jun-09	fail	depredated
Tallgrass	GRSP2009T	711277	4259008	10-Jun-09	22-Jun-09	22-Jun-09	success	
Tallgrass	GRSP2014T	711938	4259350	25-Jun-09	25-Jun-09	28-Jun-09	fail	depredated
Tallgrass	GRSP2022T	710696	4254304	09-Jul-09	09-Jul-09	13-Jul-09	fail	destruction
Tallgrass	GRSP2023T	711073	4262342	09-Jul-09	09-Jul-09	13-Jul-09	fail	depredated
Tallgrass	GRSP2024T	712101	4258875	13-Jul-09	21-Jul-09	21-Jul-09	success	
Gray Catbird								
Pipestone	GRCA6004P	714343	4876918	06-Jul-09	06-Jul-09	06-Jul-09	success	
Pipestone	GRCA6010P	714477	4876416	20-Jul-09	01-Aug-09	01-Aug-09	success	

Table 2. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Final Result
Mourning Dove								
Homestead	MODO3001H	684252	4462201	20-May-09	04-Jun-09	08-Jun-09	fail	depredated
Homestead	MODO4006H	684198	4462105	04-Jun-09	15-Jun-09	15-Jun-09	success	
Pipestone	MODO6009P	714431	4876796	20-Jul-09	26-Jul-09	26-Jul-09	success	
Tallgrass	MODO1003T	711050	4259942	14-May-09	24-May-09	27-May-09	fail	depredated
Tallgrass	MODO1005T	710168	4262840	18-May-09	18-May-09	21-May-09	fail	depredated
Tallgrass	MODO1009T	711931	4256381	30-May-09	15-Jun-09	15-Jun-09	success	
Tallgrass	MODO1017T	711728	4256316	15-Jun-09	18-Jun-09	22-Jun-09	fail	depredated
Tallgrass	MODO1020T	711177	4262554	30-Jun-09	30-Jun-09	02-Jul-09	fail	depredated
Tallgrass	MODO1024T	711279	4259695	10-Jul-09	10-Jul-09	13-Jul-09	fail	abandoned
Tallgrass	MODO2002T	711663	4259475	19-May-09	27-May-09	27-May-09	success	
Tallgrass	MODO2011T	711269	4260104	24-Jun-09	29-Jun-09	02-Jul-09	fail	abandoned
Tallgrass	MODO2012T	711841	4256395	24-Jun-09	02-Jul-09	06-Jul-09	fail	depredated
Northern Bobwhite								
Homestead	NOBO7011H	684516	4461963	05-Jun-09	22-Jun-09	22-Jun-09	success	
Red-winged Blackbird								
Homestead	RWBL3002H	684187	4462229	28-May-09	11-Jun-09	11-Jun-09	success	
Homestead	RWBL3003H	684248	4462254	11-Jun-09	22-Jun-09	22-Jun-09	success	
Homestead	RWBL3007H	684118	4462259	23-Jun-09	03-Jul-09	03-Jul-09	success	
Homestead	RWBL3009H	684218	4462279	01-Jul-09	13-Jul-09	13-Jul-09	success	
Homestead	RWBL4001H	684135	4461874	19-May-09	22-May-09	25-May-09	fail	depredated
Homestead	RWBL4002H	684124	4462259	19-May-09	08-Jun-09	08-Jun-09	success	
Homestead	RWBL4003H	684113	4462167	19-May-09	11-Jun-09	11-Jun-09	success	
Homestead	RWBL4004H	684126	4462214	21-May-09	04-Jun-09	04-Jun-09	success	
Homestead	RWBL4009H	684292	4462031	04-Jun-09	04-Jun-09	08-Jun-09	fail	depredated

Table 2. continued.

Location	Nest ID	Easting	Northing	Date Found	Last Date Active	Last Date Checked	Fate	Final Result
Red-winged Blackbird, cont.								
Homestead	RWBL4010H	684158	4461807	03-Jun-09	11-Jun-09	15-Jun-09	fail	depredated
Homestead	RWBL7001H	684152	4462223	21-May-09	25-May-09	04-Jun-09	fail	depredated
Homestead	RWBL7002H	684404	4462006	22-May-09	11-Jun-09	15-Jun-09	fail	parasitism
Homestead	RWBL7003H	684252	4462257	22-May-09	01-Jun-09	04-Jun-09	fail	depredated
Homestead	RWBL7007H	684195	4462076	04-Jun-09	23-Jun-09	23-Jun-09	success	
Pipestone	RWBL5005P	714306	4877070	13-Jul-09	30-Jul-09	01-Aug-09	fail	destruction
Pipestone	RWBL5006P	714160	4877259	15-Jul-09	22-Jul-09	22-Jul-09	success	
Pipestone	RWBL5007P	714513	4876951	15-Jul-09	26-Jul-09	30-Jul-09	fail	depredated
Pipestone	RWBL6006P	714312	4877055	13-Jul-09	13-Jul-09	16-Jul-09	fail	destruction
Pipestone	RWBL7004P	714280	4876778	28-May-09	28-May-09	01-Jun-09	fail	depredated
Ring-necked Pheasant								
Pipestone	RNEP6002P	714401	4877476	29-Jun-09	29-Jun-09	02-Jul-09	fail	depredated
Song Sparrow								
Pipestone	SOSP7005P	714260	4876798	28-May-09	11-Jun-09	15-Jun-09	fail	depredated
Upland Sandpiper								
Tallgrass	UPSA1010T	711605	4259288	30-May-09	30-May-09	02-Jun-09	fail	depredated
Tallgrass	UPSA1011T	711857	4256355	02-Jun-09	02-Jun-09	08-Jun-09	fail	depredated
Tallgrass	UPSA2001T	711378	4259859	14-May-09	18-May-09	21-May-09	fail	depredated
Wild Turkey								
Pipestone	WITU6005P	713907	4876412	13-Jul-09	26-Jul-09	26-Jul-09	success	



Table 3. Vegetation measurements at grassland bird nests at Tallgrass Prairie National Preserve, Kansas, Pipestone National Monument, Minnesota, and Homestead National Monument, Nebraska, USA, in 2008. Listed for each nest name (Nest ID) is height of nest above ground at lowest rim of nest entrance (Ht; cm), average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Tallgrass Prairie National Preserve													
CONI1008T	22-Jul	0.0	209	0	10	15	15	90	2.46	1.88	2.88	0.41	1
CONI2008T	24-Jul	0.0	380	0	30	35	45	55	1.52	1.13	2.00	0.58	3
CONI2013T	22-Jul	0.0	209	0	10	15	15	90	2.46	1.88	2.88	0.41	1
CONI2020T	31-Jul	0.0	802	0	5	10	<5	90	1.42	0.88	1.88	0.71	1
COPO1007T	1-Jul	0.0	209	0	10	10	10	95	2.06	1.56	2.69	0.55	1
DICK1019T	2-Jul	21.7	496	0	40	95	100	1	1.88	1.75	2.13	0.20	3
DICK1020T	1-Jul	14.9	1232	0	100	35	25	0	1.88	1.38	2.69	0.70	1
DICK1021T	8-Jul	15.1	468	0	40	85	75	0	2.65	2.31	2.81	0.19	1
DICK1022T	11-Jul	35.2	621	70	50	50	30	0	3.60	3.25	4.00	0.21	1
DICK1024T	23-Jul	19.4	802	0	90	35	20	1	3.21	2.88	3.88	0.31	1
DICK1026T	15-Jul	17.1	1161	0	30	90	75	1	2.81	2.44	3.13	0.24	2
DICK1027T	23-Jul	10.3	875	0	80	10	85	5	3.69	3.13	4.56	0.39	2
DICK1031T	22-Jul	19.5	1082	0	35	55	40	5	1.50	1.13	1.94	0.54	1
DICK1032T	30-Jul	21.6	271	0	65	50	90	1	2.90	2.56	3.31	0.26	2
DICK1033T	23-Jul	20.1	659	0	90	45	50	0	2.60	2.13	2.94	0.31	2
DICK2007T	20-Jun	5.0	652	0	85	40	10	20	1.21	1.06	1.38	0.26	0
DICK2009T	2-Jul	16.2	246	0	65	80	75	1	2.27	1.31	2.88	0.69	1
DICK2010T	2-Jul	14.8	408	0	20	95	50	15	2.58	2.25	3.06	0.31	1
DICK2012T	8-Jul	14.1	710	0	45	70	80	1	2.42	2.25	2.69	0.18	2

Table 3. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Tallgrass Prairie National Preserve, cont.													
DICK2016T	11-Jul	17.8	935	0	100	45	45	0	2.69	2.44	2.81	0.14	2
DICK2018T	22-Jul	11.9	598	0	40	70	45	1	3.00	2.50	3.69	0.40	1
DICK2019T	16-Jul	14.2	814	0	60	70	75	0	2.33	1.31	3.25	0.83	2
DICK2021T	30-Jul	13.3	368	0	55	95	80	0	2.88	2.81	2.94	0.04	2
DICK2022T	16-Jul	16.5	628	0	45	80	65	0	2.98	2.50	3.25	0.25	2
DICK2023T	22-Jul	11.2	1031	0	65	20	30	25	2.81	2.06	3.75	0.60	1
DICK7005T	25-Jul		240	0	65	45	30	1	2.35	2.00	3.00	0.42	1
EAME1001T	3-Jun	3.9	694	0	50	20	70	0	0.81	0.69	0.88	0.23	0
EAME1002T	10-Jun	3.2	139	0	15	65	75	1	0.69	0.00	2.06	3.00	1
EAME1005T	24-Jun		690	0	95	50	75	0	3.04	2.81	3.44	0.21	1
EAME1011T	16-Jun	4.1	226	0	65	55	45	1	2.35	2.13	2.81	0.29	1
EAME1013T	1-Jul	4.4	1278	0	95	10	20	0	2.69	0.00	4.06	1.51	2
EAME1029T	31-Jul	2.1	431	0	40	55	15	5	1.08	0.69	1.75	0.98	0
EAME2005T	1-Jul	1.5	1165	0	90	50	20	1	0.88	0.44	1.44	1.14	1
EAME2011T	1-Jul	4.3	1012	0	60	40	30	1	1.92	1.69	2.06	0.20	1
EAME2025T	31-Jul	2.9	1138	0	25	20	65	15	1.40	1.25	1.50	0.18	1
GRSP1003T	10-Jun	2.0	1020	0	20	70	80	1	0.98	0.81	1.06	0.26	2
GRSP1009T	24-Jun	3.2	1250	0	95	50	75	0	2.83	2.69	2.94	0.09	1
GRSP1012T	23-Jun	1.4	929	0	30	65	75	5	2.13	1.81	2.56	0.35	2
GRSP1014T	19-Jun	0.5	1028	1	85	60	30	1	1.56	1.31	2.00	0.44	1
GRSP1028T	31-Jul	2.6	545	0	1	100	100	0	1.52	0.94	2.06	0.74	1
GRSP1034T	31-Jul	4.4	840	0	25	45	100	0	1.40	0.63	1.88	0.90	1
GRSP1035T	31-Jul	2.8	1311	0	10	5	100	0	1.38	1.31	1.50	0.14	2
GRSP1036T	31-Jul	3.2	800	0	5	85	95	0	1.85	1.13	2.38	0.67	2

Table 3. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Tallgrass Prairie National Preserve, cont.													
GRSP2002T	16-Jun	3.8	222	0	60	50	45	1	1.54	0.94	2.00	0.69	1
GRSP2024T	23-Jul		113	0	45	55	75	1	1.73	1.31	2.31	0.58	2
HESP1018T	2-Jul		306	0	25	85	90	1	2.67	2.50	3.00	0.19	3
HESP1023T	9-Jul	3.8	971	0	85	60	60	0	1.19	0.69	1.69	0.84	1
HESP1025T	23-Jul	13.8	801	0	20	100	45	0	3.31	3.06	3.44	0.11	2
HESP2014T	22-Jul		1148	0	60	30	45	5	0.90	0.56	1.19	0.70	1
LASP1006T	19-Jun	3.0	100	0	95	35	10	1	1.35	1.00	2.00	0.74	0
MODO1017T	8-Jul	1.1	219	0	15	65	40	10	2.33	1.81	2.94	0.48	1
MODO2004T	16-Jun	0.0	280	0	40	60	10	50	1.08	0.38	1.56	1.10	1
MODO2015T	15-Jul		231	0	50	35	10	35	0.75	0.31	1.00	0.92	0
UPSA2006T	1-Jul	1.8	461	0	35	65	20	1	1.88	0.94	3.06	1.13	0
UPSA2017T	11-Jul		1228	0	50	50	50	5	1.46	1.31	1.56	0.17	1
WEME2001T	1-Jul	1.9	522	1	95	30	30	1	2.42	1.75	3.56	0.75	0
Pipestone National Monument													
CCSP6018P	7-Jul	32.5	2	50	35	45	85	0	2.73	2.56	3.00	0.16	1
COYE6022P	8-Jul	12.5	5	40	50	90	85	0	6.90	4.38	11.19	0.99	2
RNEP6015P	8-Jul		56	25	15	80	95	0	4.00	2.88	5.06	0.55	2
RWBL6004P	1-Jul	52.5	182	0	40	90	85	0	8.38	6.88	9.94	0.37	2
RWBL6007P	1-Jul	70.0	143	0	40	90	75	0	9.61	5.00	12.02	0.73	1
RWBL6008P	25-Jun	70.0	56	0	0	100	5	0	2.44	0.00	7.31	3.00	3
RWBL6009P	25-Jun	42.5	43	0	65	65	95	0	5.44	4.06	7.88	0.70	1
RWBL6014P	25-Jun	13.3	80	0	25	95	60	0	6.10	3.38	7.88	0.74	2
WITU6001P	13-Jun		13	1	1	70	95	0	3.15	0.25	6.81	2.09	3

Table 3. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Homestead National Monument													
BRTH4008H	2-Jul	9.5	1	85	0	25	0	0	6.10	4.81	8.31	0.57	1
DICK3016H	23-Jun	10.1	28	0	95	20	15	0	4.00	3.31	4.88	0.39	2
DICK3018H	2-Jul	10.0	1	0	85	55	5	0	5.85	5.06	6.69	0.28	2
DICK3019H	10-Jul	9.8	1	0	75	30	10	0	5.21	5.06	5.44	0.07	0
DICK3020H	21-Jul	9.6	27	15	40	65	10	20	5.96	5.69	6.25	0.09	3
DICK3021H	21-Jul	9.9	1	80	25	30	10	0	7.79	7.19	8.31	0.14	0
DICK3022H	15-Jul	9.7	41	20	30	90	0	0	5.25	5.06	5.56	0.10	1
DICK3023H			1										0
DICK4013H	10-Jul	8.0	1	0	80	30	0	0	9.17	8.38	10.06	0.18	2
DICK4014H			1										0
DICK4015H	10-Jul	9.9	1	0	80	55	15	10	4.81	4.50	5.44	0.19	2
DICK4016H	15-Jul	9.5	1	15	70	55	10	0	6.96	6.63	7.50	0.13	0
DICK4017H	10-Jul	9.8	1	65	50	30	15	0	2.71	0.00	7.13	2.63	0
DICK4018H	23-Jul	9.6	1	35	55	70	0	0	7.31	6.44	7.94	0.21	3
GRCA3014H	9-Jun	10.1	1	65	75	10	0	0	7.42	4.56	11.88	0.99	1
MODO4009H	9-Jun	1.0	1	90	20	0	0	0	7.48	4.50	11.44	0.93	1
RWBL3001H	12-Jun	10.0	1	0	95	5	15	0	6.77	5.31	8.56	0.48	3
RWBL3003H	9-Jun	10.0	1	0	90	0	25	0	5.08	4.44	5.94	0.30	1
RWBL3004H	20-Jun	7.5	1	0	95	5	15	0	7.19	4.06	9.56	0.77	3
RWBL3006H	9-Jun	9.6	1	10	75	20	50	0	4.81	4.50	5.13	0.13	3
RWBL3007H	12-Jun	10.0	1	0	90	0	25	0	7.69	6.25	9.19	0.38	3
RWBL3008H	9-Jun	9.5	1	30	100	5	0	0	6.27	4.94	8.31	0.54	3
RWBL3009H	9-Jun	9.1	4	45	85	0	20	0	8.98	8.00	10.81	0.31	1
RWBL3010 H	9-Jun	9.7	1	90	35	0	25	0	6.44	3.50	8.00	0.70	1

Table 3. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Homestead National Monument, cont.													
RWBL3011H	9-Jun	9.8	1	95	40	0	25	0	6.77	3.44	8.94	0.81	1
RWBL3012H	9-Jun	9.4	1	0	85	15	10	0	2.75	0.56	4.00	1.25	2
RWBL3013H	9-Jun	9.6	1	0	90	0	5	0	8.15	4.63	10.00	0.66	1
RWBL3017H	10-Jul	9.9	28	0	85	70	15	5	6.25	5.44	7.00	0.25	3
RWBL4002H	9-Jun	9.5	1	0	75	20	5	5	4.58	3.50	5.25	0.38	1
RWBL4006H	9-Jun	9.7	1	5	90	10	10	0	5.40	5.06	5.75	0.13	1
RWBL4007H	9-Jun	9.0	1	0	90	25	0	0	2.92	1.50	3.75	0.77	3
RWBL4010H	20-Jun	9.0	1	0	90	10	20	0	4.92	3.06	6.63	0.72	3
RWBL4011H	9-Jun	9.9	1	35	80	40	5	0	5.94	5.56	6.44	0.15	1
WITU4001H	22-May	13.0	1	0	35	70	85	0	5.60	5.38	6.06	0.12	3

Table 4. Vegetation measurements at grassland bird nests at Tallgrass Prairie National Preserve, Kansas, Pipestone National Monument, Minnesota, and Homestead National Monument, Nebraska, USA, in 2009. Listed for each nest name (Nest ID) is height of nest above ground at lowest rim of nest entrance (Ht; cm), average distance to edge (Edge), percent functional cover for five cover classes (Woody, Forb, Grass, Litter, Bare), visual obstruction reading (VOR; dm), minimum visual obstruction reading (VOR<sub>min</sub>), maximum visual obstruction reading (VOR<sub>max</sub>), visual obstruction reading heterogeneity (VOR<sub>het</sub>), and years since last burn at time of measurement (BY). See chapter 2 for more extensive description of data collection.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Tallgrass Prairie National Preserve													
CONI2005T	1-Jul	0.0	462	0	25	20	10	50	1.02	0.69	1.50	0.80	0
CONI2013T	14-Jul	0.0	414	0	5	15	5	75	1.31	1.00	1.50	0.38	0
CONI2018T	17-Jul	0.0	314	0	15	35	15	45	1.96	1.44	2.44	0.51	1
DICK1013T	30-Jun	32.0	246	70	5	15	15	0	2.69	0.63	4.25	1.35	1
DICK1015T	1-Jul	17.0	397	0	45	45	20	0	2.21	1.19	3.19	0.91	2
DICK1019T	9-Jul	15.0	190	0	25	55	30	0	2.71	2.06	3.44	0.51	1
DICK1023T	16-Jul	7.0	132	0	75	15	10	15	0.52	0.38	0.63	0.48	0
DICK1025T	17-Jul	19.0	299	0	10	60	40	0	3.06	2.25	3.75	0.49	1
DICK2007T	1-Jul	28.0	62	40	10	35	20	0	2.35	1.63	2.81	0.50	2
DICK2015T	8-Jul	22.5	124	30	15	40	25	0	3.81	2.81	4.50	0.44	2
DICK2016T	17-Jul	33.0	429	80	15	5	10	<1	2.33	1.88	2.94	0.46	1
DICK2017T	17-Jul	39.0	270	85	5	10	10	5	3.85	3.44	4.44	0.26	1
DICK2019T	16-Jul		378	0	70	20	20	0	2.96	2.56	3.69	0.38	2
DICK2021T	16-Jul	7.2	318	0	40	30	10	25	0.42	0.19	0.63	1.05	0
DICK2025T	16-Jul	7.2	162	0	35	55	10	10	2.42	2.00	3.25	0.52	0
EAME1001T	16-Jun		311	0	10	70	25	<1	2.48	2.25	2.75	0.20	2
EAME1002T	13-Jun	2.0	200	0	55	20	20	5	2.56	2.13	3.19	0.41	2
EAME1006T	8-Jun	4.0	444	0	20	55	40	5	1.38	1.25	1.56	0.23	2
EAME1007T	11-Jun		272	0	60	35	20	0	1.85	0.06	3.00	1.58	1

Table 4. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Tallgrass Prairie National Preserve, cont.													
EAME1012T	13-Jun	5.5	188	0	30	50	30	0	2.58	2.44	2.69	0.10	2
EAME1014T	16-Jun	2.0	233	0	20	65	15	5	1.23	0.81	1.75	0.76	0
EAME1018T	15-Jul		403	0	30	35	20	20	1.46	1.19	1.81	0.43	0
EAME1022T	17-Jul	2.8	218	0	20	50	25	10	2.21	1.63	3.25	0.74	1
EAME2010T	1-Jul	3.5	257	0	25	55	5	20	1.42	0.75	1.75	0.71	0
GRSP1004T	8-Jun		482	0	30	60	20	<1	1.96	1.81	2.06	0.13	1
GRSP1026T	15-Jul	2.0	395	0	25	35	25	15	1.48	1.06	1.75	0.46	0
GRSP2003T	8-Jun		285	0	15	60	20	5	1.52	0.75	2.50	1.15	1
GRSP2004T	15-Jun		392	0	40	50	20	5	2.02	1.81	2.31	0.25	2
GRSP2008T	22-Jun	1.5	167	0	30	40	35	<1	1.50	1.31	1.63	0.21	2
GRSP2009T	26-Jun	3.5	274	0	45	25	40	0	2.54	2.31	2.88	0.22	2
GRSP2014T	13-Jul	2.5	295	0	30	55	20	0	2.38	2.25	2.56	0.13	2
GRSP2022T	13-Jul	0.5	437	0	30	35	15	25	0.65	0.31	0.81	0.77	0
GRSP2023T	17-Jul	1.5	236	0	10	65	35	0	2.00	0.94	2.56	0.81	1
GRSP2024T	16-Jul	1.4	531	0	20	50	35	<1	1.85	1.75	2.06	0.17	2
MODO1003T	8-Jun		188	0	20	40	40	<1	1.98	1.75	2.38	0.32	2
MODO1005T	17-Jun		143	0	15	30	45	15	1.40	1.13	1.81	0.49	1
MODO1009T	24-Jun	1.0	427	0	25	40	10	30	1.06	0.69	1.63	0.88	0
MODO1017T	13-Jul		350	0	15	50	5	30	0.88	0.38	1.19	0.93	0
MODO1020T	17-Jul		171	0	10	35	15	45	2.04	1.31	2.56	0.61	1
MODO1024T	16-Jul	0.4	247	0	30	15	30	30	1.29	1.25	1.38	0.10	2
MODO2002T	3-Jun	3.0	191	0	35	40	15	15	2.21	2.00	2.56	0.25	2
MODO2011T	16-Jul	3.0	159	0	30	10	30	35	3.10	2.06	4.31	0.72	2
MODO2012T	14-Jul	2.0	328	0	20	40	15	30	1.35	0.88	1.94	0.78	0

Table 4. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Tallgrass Prairie National Preserve, cont.													
UPSA1010T	24-Jun		494	0	15	45	45	0	2.10	1.13	3.00	0.89	2
UPSA1011T	23-Jun		422	0	10	65	5	25	1.35	1.25	1.44	0.14	0
UPSA2001T	4-Jun	5.0	400	0	25	20	60	5	1.56	1.50	1.63	0.08	2
Pipestone National Monument													
AMGO6008P	30-Jul	174.0	0	100	0	30	10	60	3.08	2.06	3.94	0.61	0
CCSP5001P	7-Jul	7.2	148	40	20	15	95	5	3.33	2.44	3.81	0.41	2
CCSP5002P	7-Jul		66	80	5	25	95	5	2.38	1.69	2.75	0.45	2
CCSP5004P	14-Jul	29.0	29	90	5	15	20	5	2.50	1.88	3.06	0.48	2
CCSP5009P	30-Jul	41.5	114	20	30	10	95	5	3.31	2.63	4.13	0.45	2
CCSP6003P	8-Jul	33.2	44	90	5	15	95	5	2.60	1.75	3.38	0.62	2
CCSP6012P	30-Jul	42.5	0	30	0	25	95	0	2.71	1.19	3.50	0.85	1
CCSP6014P	30-Jul	30.0	0	70	10	20	5	95	3.08	2.81	3.25	0.14	0
EAKI6007P	30-Jul	198.5	2	15	0	50	65	10	12.92	7.75	16.56	0.68	1
FISP5003P	7-Jul	29.5	60	95	<1	10	100	0	3.60	2.06	6.25	1.16	2
FISP5010P	30-Jul	40.5	43	30	10	30	95	5	3.08	1.94	4.13	0.71	2
FISP6001P	11-Jun	9.0	146	35	10	45	90	5	1.90	1.19	2.69	0.79	2
FISP6013P	30-Jul	27.0	84	35	20	40	10	90	4.27	3.88	4.75	0.20	0
GRCA6004P	11-Jul	113.5	0	100	70	5	20	30	2.73	1.69	3.56	0.69	1
GRCA6010P	30-Jul	134.0	0	100	0	85	90	5	2.38	0.31	3.50	1.34	0
MODO6009P	30-Jul	53.0	10	100	0	15	100	5	1.85	0.00	2.81	1.52	0
RNEP6002P	7-Jul	6.5	80	5	25	35	95	5	2.19	1.38	2.94	0.71	2
RWBL5005P	30-Jul	128.5	11	95	0	5	5	10	1.77	0.00	5.31	3.00	1
RWBL5006P	30-Jul	93.5	3	55	5	25	65	15	4.29	1.19	7.25	1.41	1
RWBL5007P	30-Jul	93.5	8	0	50	5	100	0	0.58	0.00	1.75	3.00	0



Table 4. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Pipestone National Monument, cont.													
RWBL6006P	30-Jul	96.5	0	10	80	30	100	<1	3.15	0.00	9.44	3.00	1
RWBL7004P	11-Jun	80.0	69	0	0	100	100	0	4.81	2.44	8.00	1.16	1
SOSP7005P	7-Jul	2.5	202	30	30	40	100	0	3.46	2.56	4.81	0.65	1
WITU6005P	30-Jul	0.0	39	0	10	30	100	0	4.79	2.81	7.31	0.94	1
Homestead National Monument													
DICK3004H	22-Jul	22.5	16	1	5	90	95	1	12.60	10.25	16.38	0.49	5
DICK3005H	7-Jul	10.0	78	45	20	75	95	1	5.77	5.25	6.19	0.16	1
DICK3006H	23-Jul	42.5	69	80	15	40	95	1	4.67	1.31	6.81	1.18	1
DICK3010H	23-Jul	27.5	46	0	75	30	95	1	6.60	5.25	8.19	0.44	1
DICK4008H	1-Jul	15.0	65	0	15	95	95	1	5.21	4.31	6.44	0.41	5
DICK4012H	22-Jul	20.0	13	10	20	90	95	0	8.77	7.81	10.19	0.27	1
DICK4013H	22-Jul	20.0	60	55	25	75	95	1	5.85	5.50	6.31	0.14	1
DICK4014H	14-Jul	70.0	15	65	35	10	95	1	7.96	5.44	11.19	0.72	5
DICK4016H	22-Jul	65.0	8	65	30	5	95	1	8.19	6.00	10.13	0.50	5
DICK4017H	22-Jul	47.5	32	50	0	45	95	1	4.02	0.13	7.56	1.85	5
DICK7010H	30-Jun	12.5	53	1	80	45	95	1	8.83	5.50	13.69	0.93	1
MODO3001H	1-Jul	0.0	49	0	30	65	95	1	5.00	3.88	7.13	0.65	5
MODO4006H	23-Jul	0.0	80	1	80	10	95	1	10.17	8.88	11.88	0.30	5
NOBO7011H	30-Jun	2.5	58	0	5	95	95	1	5.17	4.63	5.75	0.22	1
RWBL3002H	9-Jul	37.5	49	5	55	5	90	5	7.50	6.31	8.25	0.26	5
RWBL3003H	9-Jul	82.5	100	85	15	5	90	5	8.81	7.06	10.88	0.43	1
RWBL3007H	8-Jul	92.5	12	75	15	15	95	1	11.21	6.50	17.94	1.02	5
RWBL3009H	23-Jul	42.5	36	0	15	90	95	1	8.73	5.50	11.63	0.70	1
RWBL4001H	22-Jul	45.0	31	50	35	0	90	5	8.25	8.19	8.38	0.02	5

Table 4. continued.

Nest ID	Date	Ht	Edge	Woody	Forb	Grass	Litter	Bare	VOR	VOR <sub>min</sub>	VOR <sub>max</sub>	VOR <sub>het</sub>	BY
Homestead National Monument, cont.													
RWBL4002H	23-Jun	35.0	107	1	90	0	80	5	9.02	7.06	10.50	0.38	5
RWBL4003H	25-Jun	92.5	68	5	95	5	95	5	6.92	5.88	8.88	0.43	5
RWBL4004H	25-Jun	40.0	73	10	90	5	95	5	7.58	5.69	8.69	0.40	5
RWBL4009H	22-Jul	92.5	16	40	15	45	85	5	6.81	5.69	8.56	0.42	1
RWBL4010H	22-Jul	90.0	1	70	15	55	95	1	9.65	5.81	13.19	0.76	2
RWBL7002H	22-Jul	137.5	28	95	75	5	95	5	7.31	6.56	8.50	0.26	1
RWBL7003H	17-Jun	95.0	4	1	70	60	95	1	6.50	4.38	7.63	0.50	1
RWBL7007H	22-Jul	85.0	49	95	35	5	95	1	8.73	6.56	11.00	0.51	5

Table 5. Generalized linear model selection results for target species nest survival at Homestead National Monument (Homestead), Nebraska, and Tallgrass Prairie National Preserve (Tallgrass), Kansas, USA, in 2008. Models analyses were conducted in Program R using binomial family and a log-exposure link.

Model Structure	AIC <sub>c</sub> <sup>a</sup>	K <sup>b</sup>	ΔAIC <sub>c</sub> <sup>c</sup>	w <sub>i</sub> <sup>d</sup>
Dickcissels at Homestead (11 nests, 41 observations)				
Null model	32.68	2	0.00	0.52
Nest height <sup>e</sup> + distance to edge <sup>f</sup> + burn year <sup>g</sup>	34.65	7	1.97	0.20
Nest age <sup>h</sup> + day in nesting season <sup>i</sup>	35.54	4	2.86	0.13
VOR <sup>j</sup> + VOR heterogeneity <sup>k</sup>	35.92	4	3.24	0.10
Woody <sup>l</sup> + forb <sup>m</sup> + grass <sup>n</sup> + litter <sup>o</sup>	37.65	6	4.96	0.04
VOR + VOR heterogeneity + woody + forb + grass + litter	41.87	8	9.19	0.01
Dickcissels at Tallgrass (19 nests, 40 observations)				
Null model	53.67	2	0.00	0.52
VOR + VOR heterogeneity	55.14	4	1.48	0.25
Woody + forb + grass + litter	57.07	6	3.41	0.09
Nest age + day in nesting season	58.16	4	4.49	0.05
Nest height + distance to edge + burn year	58.44	7	4.77	0.05
VOR + VOR heterogeneity + woody + forb + grass + litter	58.99	8	5.33	0.04
Eastern Meadowlark at Tallgrass (10 nests, 31 observations)				
VOR + VOR heterogeneity	24.72	4	0.00	0.86
Null model	28.93	2	4.21	0.10
Nest age + day in nesting season	31.82	4	7.09	0.02
Grass + litter + bare <sup>p</sup>	34.33	5	9.61	0.01
Distance to edge + burn year	34.98	5	10.25	0.01
Grasshopper Sparrow at Tallgrass (10 nests, 33 observations)				
Null model	25.76	2	0.00	0.52
Nest age + day in nesting season	27.86	4	2.10	0.18
Distance to edge + burn year	28.22	4	2.45	0.15
VOR + VOR heterogeneity	28.76	4	3.00	0.12
Woody + grass + litter + bare	31.33	6	5.57	0.03
VOR + VOR heterogeneity + woody + grass + litter + bare	35.75	7	9.99	0.00

<sup>a-d</sup> AIC<sub>c</sub> = Akaike's Information Criterion adjusted for small sample sizes; K = number of model parameters; ΔAIC<sub>c</sub> = relative AIC<sub>c</sub>; w<sub>i</sub> = Akaike weight

<sup>e-g</sup> ht = height of nest rim above the ground; edge = average distance to edge; BY = years since last burn

<sup>h-i</sup> age = number of days since the start of incubation; day = number of days since May 1

<sup>j-k</sup> VOR = average visual obstruction reading, VOR.het = VOR heterogeneity

<sup>l-p</sup> woody = % woody ground cover; forb = % forb ground cover; grass = % grass ground cover; litter = % litter cover; bare = % bare ground.

Table 6. Generalized linear model selection results for target species nest survival at Homestead National Monument (Homestead), Nebraska, and Tallgrass Prairie National Preserve (Tallgrass), Kansas, USA, in 2009. Models analyses were conducted in Program R using binomial family and a log-exposure link.

Model Structure	AIC <sub>c</sub> <sup>a</sup>	K <sup>b</sup>	ΔAIC <sub>c</sub> <sup>c</sup>	w <sub>i</sub> <sup>d</sup>
Dickcissels at Homestead (10 nests, 32 observations)				
Woody <sup>l</sup> + forb <sup>m</sup> + grass <sup>n</sup>	32.40	5	0.00	0.58
Null model	34.01	2	1.61	0.26
Nest age <sup>h</sup> + day in nesting season <sup>i</sup>	36.54	4	4.14	0.07
VOR <sup>j</sup> + VOR heterogeneity <sup>k</sup>	36.84	4	4.44	0.06
Nest height <sup>e</sup> + distance to edge <sup>f</sup> + burn year <sup>g</sup>	38.69	5	6.29	0.02
Dickcissels at Tallgrass (11 nests, 33 observations)				
Null model	32.44	2	0.00	0.73
Woody + forb + grass + litter <sup>o</sup>	36.76	6	4.32	0.08
VOR + VOR heterogeneity	36.95	4	4.51	0.08
Nest age + day in nesting season	36.97	4	4.54	0.08
Nest height + distance to edge + burn year	39.67	6	7.23	0.02
VOR + VOR heterogeneity + woody + forb + grass + litter	41.62	8	9.19	0.01
Eastern Meadowlarks at Tallgrass (9 nests, 19 observations)				
Grass + litter + bare <sup>p</sup>	23.95	5	0.00	0.43
Null model	24.35	2	0.40	0.35
Nest age + day in nesting season	26.04	4	2.09	0.15
VOR + VOR heterogeneity	28.68	4	4.73	0.04
Distance to edge + burn year Y	29.42	5	5.47	0.03
Grasshopper Sparrows at Tallgrass (10 nests, 20 observations)				
Null model	24.08	2	0.00	0.79
VOR + VOR heterogeneity	28.83	4	4.75	0.07
Nest age + day in nesting season	29.03	4	4.95	0.07
Grass + litter + bare	29.51	5	5.43	0.05
Distance to edge + burn year	31.96	5	7.88	0.02
VOR + VOR heterogeneity + grass + litter + bare	35.22	7	11.14	0.00

<sup>a-d</sup> AIC<sub>c</sub> = Akaike's Information Criterion adjusted for small sample sizes; K = number of model parameters; ΔAIC<sub>c</sub> = relative AIC<sub>c</sub>; w<sub>i</sub> = Akaike weight

<sup>e-g</sup> ht = height of nest rim above the ground; edge = average distance to edge; BY = years since last burn

<sup>h-i</sup> age = number of days since the start of incubation; day = number of days since May 1

<sup>j-k</sup> VOR = average visual obstruction reading, VOR.het = VOR heterogeneity

<sup>l-p</sup> woody = % woody ground cover; forb = % forb ground cover; grass = % grass ground cover; litter = % litter cover; bare = % bare ground.

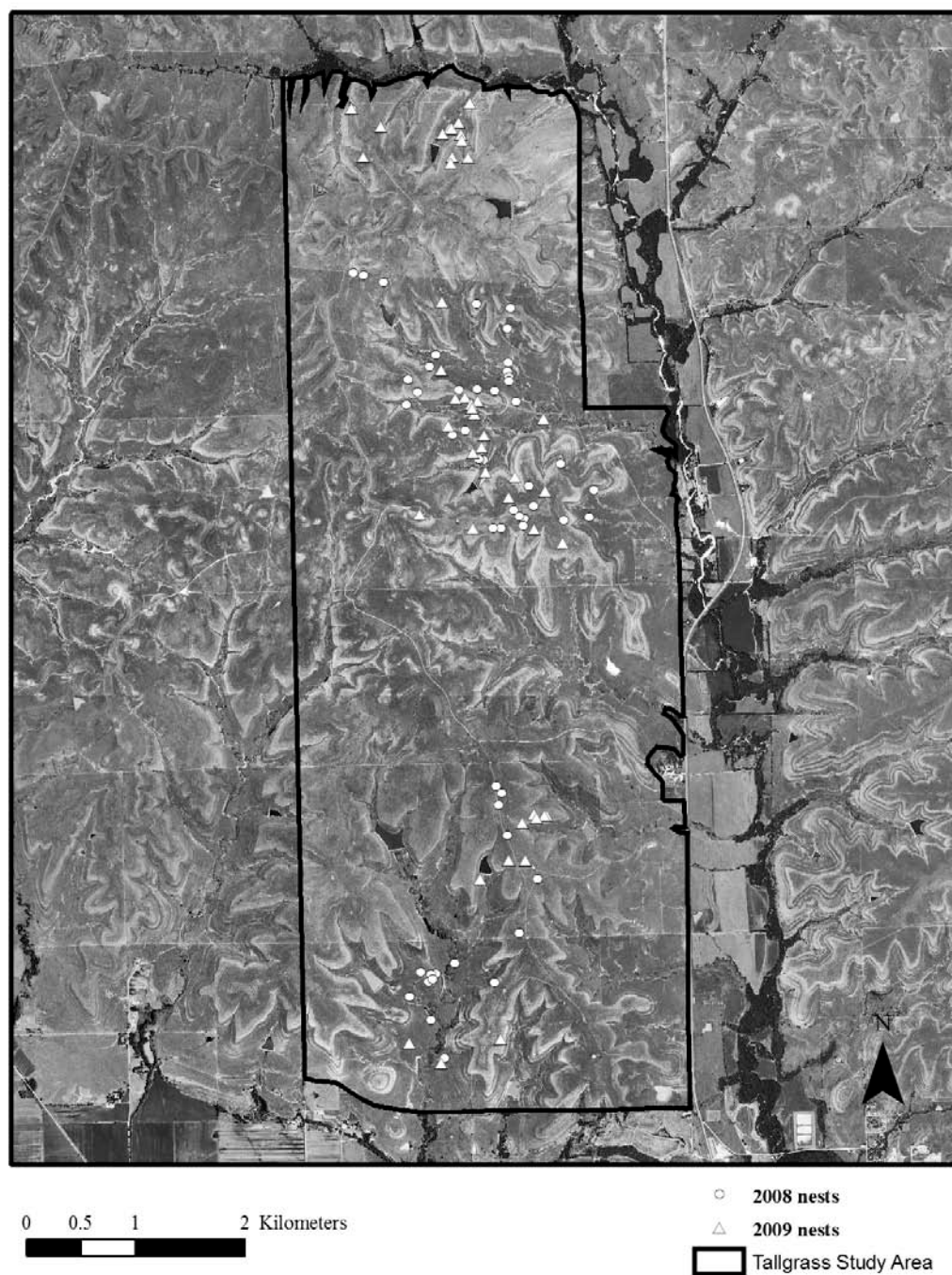


Figure 1. Location of grassland bird nests at Tallgrass Prairie National Preserve, KS, USA, in 2008 and 2009.



Figure 2. Location of grassland bird nests at Pipestone National Monument, Minnesota, USA, in 2008 and 2009.



Figure 3. Location of grassland bird nests at Homestead National Monument, Nebraska, USA, in 2008 and 2009.

## Appendix C: CHAPTER 3 SUPPLEMENTAL TABLES

Table 1. Articles in volume 72 (2008) of the Journal of Wildlife Management utilizing multi-model inference (61 of 159 articles reviewed). See methods section of chapter 4 for a description of paper categorization. Inference strength was classified as ‘strong’ (1 top model), ‘weak’ (>1 model in confidence set), ‘both’ (contained both strong and weak inference), or ‘unknown’ (insufficient information provided). Management recommendations were classified as ‘non-management’ (did not provide explicit management recommendations), ‘vague’ (did not provide explicit actions to implement), ‘specific’ (provided explicit actions to implement), or ‘adaptive’ (advocated an adaptive management approach). See chapter 4 for more extensive paper classification methods.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Baxter, et al. (1)	Survival, movements, and reproduction of translocated greater sage-grouse in strawberry valley, Utah	weak	yes	specific	yes, model-averaging	no criteria reported
Bentzen, et al. (8)	Factors influencing nesting success of king eiders on northern Alaska’s coastal plain	weak	yes	vague	no	lowest $\Delta$ AIC (no specific AIC value provided)
Bischof, et al. (1)	Hunting patterns, ban on baiting, and harvest demographics of brown bears in Sweden	unknown		specific	no	lowest AIC value (top model only)
Bishop, et al. (5)	Evaluating dependence among mule deer siblings in fetal and neonatal survival analyses	unknown	yes	specific	no	no criteria reported
Boulanger, et al. (3)	Use of occupancy models to estimate the influence of previous live captures on DNA-based detection probabilities of grizzly bears	weak		specific	no	lowest $\Delta$ AIC (no specific AIC value provided)
Bourgeois, et al. (5)	Colony-site selection drives management priorities for Yelkouan shearwater populations	weak		specific	no	models within 2 $\Delta$ AIC of top model



Table 1. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Churchwell, et al. (7)	Effects of patch-burn management on dickcissel nest success in a tallgrass prairie	weak	yes	specific	no	models within 2 $\Delta$ AIC of top model
Devries, et al. (8)	Waterfowl nesting in fall-seeded and spring-seeded cropland in Saskatchewan	weak		specific	no	models within 2 $\Delta$ AIC of top model
Diefenbach, et al. (6)	Modeling distribution of dispersal distances in male white-tailed deer	both		vague	no	no criteria reported
Doherty, et al. (1)	Greater sage-grouse winter habitat selection and energy development	both		specific	no	models within 2 $\Delta$ AIC of top model
Fondell, et al. (7)	Survival of dusky Canada goose goslings in relation to weather and annual nest success	both		vague	no	lowest AIC value (top model only)
Fratto, et al. (7)	Evaluation of turtle exclusion and escapement devices for hoop-nets	weak		vague	no	models that add up to 95% of total weight
Gorgone, et al. (4)	Modeling response of target and nontarget dolphins to biopsy darting	unknown		specific	no	no criteria reported
Guthery & Mecozzi (5)	Developing the concept of estimating bobwhite density with pointing dogs	unknown		specific	no	no criteria reported
Hagmeier, et al. (6)	Estimating numbers of black brant using sequential spring-staging sites	both		vague	yes, apart from model selection	no criteria reported
Harper, et al. (3)	Effectiveness of lethal, directed wolf-depredation control in Minnesota	unknown		specific	no	no criteria reported
Hein, et al. (8)	Male Seminole bat winter roost-site selection in a managed forest	weak	yes	specific	yes, model-averaging	models within 10% of the weight of top model

Table 1. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Howell, et al. (1)	Building hierarchical models of avian distributions for the state of Georgia	weak		vague	yes	models within 10% of the weight of top model or 4 best models
Hupp, et al. (7)	Seasonal survival of radiomarked emperor geese in western Alaska	weak		specific	yes	models within 2 $\Delta$ AIC of top model
Hurteau, et al. (5)	Fuel-reduction treatment effects on avian community structure and diversity	unknown	yes	specific	no	models within 2 $\Delta$ AIC of top model
Huwer, et al. (7)	Using human-imprinted chicks to evaluate the importance of forbs to sage-grouse	both		specific	no	no criteria reported
Johnston & Anthony (8)	Small-mammal microhabitat associations and response to grazing in Oregon	unknown		specific	no	models within 2 $\Delta$ AIC of top model
Kendall, et al. (8)	Grizzly bear density in Glacier National Park, Montana	weak	yes	specific	yes, model-averaging	models within 2 $\Delta$ AIC of top model
Kissling & Garton (3)	Forested buffer strips and breeding bird communities in southeast Alaska	both	yes	specific	yes, model-averaging	models within 4 $\Delta$ AIC of top model
Klaver, et al. (2)	Associating seasonal range characteristics with survival of female white-tailed deer	weak		vague	no	authors used weights comparatively
Lehman, et al. (8)	Merriam's turkey nest survival and factors affecting nest predation by mammals	weak		specific	no	models within 2 $\Delta$ AIC of top model

Table 1. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Linklater & Swaigood (5)	Reserve size, conspecific density, and translocation success for black rhinoceros	weak		specific	no	models within 2 $\Delta$ AIC of top model
Lischka , et al. (2)	Effects of impact perception on acceptance capacity for white-tailed deer	weak		vague	no	lowest AIC value (top model only)
Long, et al. (5)	Effects of season and scale on response of elk and mule deer to habitat manipulation	unknown	yes	specific	no	models that add up to 95% of total weight
Luukkonen, et al. (2)	Movements and survival of molt migrant Canada geese from southern Michigan	weak	yes	specific	no	authors used weights comparatively
Manning & Edge (3)	Small mammal responses to fine woody debris and forest fuel reduction in southwest Oregon	both		vague	no	no criteria reported
Mccleery, et al. (1)	Fox squirrel survival in urban and rural environments	weak	yes	vague	no	models <2 $\Delta$ AIC of top model, 'competitive'; 2-4 $\Delta$ AIC, 'plausible'; >4 $\Delta$ AIC are 'unlikely'
Mitchell, et al. (4)	Estimation of successful breeding pairs for wolves in the northern Rocky Mountains, USA	weak	yes	adaptive	no	models <2 $\Delta$ AIC of top model, 'competitive'; 2-4 $\Delta$ AIC, 'plausible'; >4 $\Delta$ AIC are 'unlikely'
Mitro, et al. (3)	Common loon survival rates and mercury in New England and Wisconsin	both	yes	specific	no	models within 4 $\Delta$ AIC of top model

Table 1. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Obbard & Howe (4)	Demography of black bears in hunted and unhunted areas of the boreal forest of Ontario	unknown	yes	specific	yes, apart from model selection	authors used weights comparatively
Ober & Hayes (2)	Influence of vegetation on bat use of riparian areas at multiple spatial scales	both		vague	no	models within 2 $\Delta$ AIC of top model
Odden, et al. (1)	Vulnerability of domestic sheep to lynx depredation in relation to roe deer density	both		specific	no	listed and discussed evidence ratios
Odell, et al. (6)	Estimation of occupied and unoccupied black-tailed prairie dog colony acreage in Colorado	weak		specific	no	no criteria reported
O'Neal, et al. (3)	Waterbird response to wetlands restored through the Conservation Reserve Enhancement Program	both		vague	no	models within 2 $\Delta$ AIC of top model
Organ, et al. (7)	Within-stand selection of Canada lynx natal dens in northwest Maine, USA	strong		specific	NA, no	no criteria reported
Perry, et al. (4)	Scale-dependent effects of landscape structure and composition on diurnal roost selection by forest bats	unknown	yes	vague	no	models within 2 $\Delta$ AIC of top model
Person & Russell (7)	Correlates of mortality in an exploited wolf population	weak		specific	no	models within 4 $\Delta$ AIC of top model
Pitt, et al. (2)	Survival and body condition of raccoons at the edge of the range	weak	yes	non-management	no	models within 2 $\Delta$ AIC of top model
Riddle, et al. (6)	The importance of habitat shape and landscape context to northern bobwhite populations	strong		specific	NA, no	not Applicable

Table 1. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Rittenhouse, et al. (1)	Resource selection by translocated three-toed box turtles in Missouri	unknown		specific	no	authors used weights comparatively
Schmutz, et al. (6)	Demography of ferruginous hawks breeding in western Canada	weak	yes	non-management	no	models within 2 $\Delta$ AIC of top model
Seckinger, et al. (4)	Effects of landscape composition on winter survival of northern bobwhites	weak	yes	vague	yes	models within 2 $\Delta$ AIC of top model
Skuldt, et al. (5)	White-tailed deer movements in a chronic wasting disease area in south- central Wisconsin	unknown		specific	no	no criteria reported
Sorensen, et al. (4)	Determining sustainable levels of cumulative effects for boreal caribou	strong		specific	NA, no	no criteria reported
Strickland & Demarais (5)	Influence of landscape composition and structure on antler size of white- tailed deer	weak	yes	specific	no	models within 2 $\Delta$ AIC of top model
Tipton, et al. (4)	Occupancy of mountain plover and burrowing owl in Colorado	unknown		vague	no	models within 2 $\Delta$ AIC of top model
Toigo , et al. (7)	Disentangling natural from hunting mortality in an intensively hunted wild boar population	weak		specific	no	used weights comparatively
Tucker, et al. (5)	Space use and habitat selection by bobcats in the fragmented landscape of south-central Iowa	unknown		vague	no	models within 2 $\Delta$ AIC of top model
Vierling, et al. (2)	Preburn characteristics and woodpecker use of burned coniferous forests	weak		specific	no	models within 2 $\Delta$ AIC of top model

Table 1. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Waltert, et al. (3)	Foot surveys of large mammals in woodlands of western Tanzania	unknown		specific	no	no criteria reported
Ward, et al. (3)	Effects of road crossings on stream and streamside salamanders	both		specific	no	models within 0-2 $\Delta$ AIC, 'substantial support'; 4-7 $\Delta$ AIC, 'less support'; >10 $\Delta$ AIC, no support
Webb & Shine (6)	Differential effects of an intense wildfire on survival of sympatric snakes	weak	yes	specific	no	models that add up to 90% of total weight
Williams, et al. (1)	Winter fidelity and apparent survival of lesser snow goose populations in the pacific flyway	strong		vague	yes, apart from model selection	models within 0-2 $\Delta$ AIC, 'substantial support'; 4-7 $\Delta$ AIC, 'less support'; >10 $\Delta$ AIC, no support
Winchell & Doherty (6)	Using California gnatcatcher to test underlying models in habitat conservation plans	weak		specific	no	no criteria reported
Yerkes, et al. (3)	Stable isotopes ( $\delta$ D, $\delta$ 13C, $\delta$ 15N) reveal associations among geographic location and condition of Alaskan northern pintails	weak		vague	no	no criteria reported
Zahratka & Shenk (4)	Population estimates of snowshoe hares in the southern Rocky Mountains	weak	yes	specific	yes, model-averaging	lowest $\Delta$ AIC (no specific AIC value provided)

<sup>a</sup> Did the authors model average?<sup>b</sup> Did the authors use the term 'uncertainty' in relation to their model selection?<sup>c</sup> Criteria authors followed for defining their confidence set of models

Table 2. Articles in volume 22 (2008) of Conservation Biology utilizing multi-model inference (15 of 105 articles reviewed). See methods section of chapter 4 for a description of paper categorization. Inference strength was classified as ‘strong’ (1 top model), ‘weak’ (>1 model in confidence set), ‘both’ (contained both strong and weak inference), or ‘unknown’ (insufficient information provided). Management recommendations were classified as ‘non-management’ (did not provide explicit management recommendations), ‘vague’ (did not provide explicit actions to implement), ‘specific’ (provided explicit actions to implement), or ‘adaptive’ (advocated an adaptive management approach). See chapter 4 for more extensive paper classification methods.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Bayne, et al. (5)	Impacts of Chronic Anthropogenic Noise from Energy-Sector Activity on Abundance of Songbirds in the Boreal Forest	unknown		non-management	no	no criteria reported
Carroll & Johnson (4)	The Importance of Being Spatial (and Reserved): Assessing Northern Spotted Owl Habitat Relationships with Hierarchical Bayesian Models	Strong		specific	yes	no criteria reported
Davis, et al. (5)	Effects of an Alien Ant Invasion on Abundance, Behavior, and Reproductive Success of Endemic Island Birds	Strong		non-management	yes, apart from model selection	models within 2 $\Delta$ AIC of top model
Ferretti, et al. (4)	Loss of Large Predatory Sharks from the Mediterranean Sea	unknown		non-management	no	no criteria reported
Keller, et al. (1)	Preventing the Spread of Invasive Species: Economic Benefits of Intervention Guided by Ecological Predictions	unknown		specific	no	no criteria reported

Table 2. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Lees & Peres (2)	Conservation Value of Remnant Riparian Forest Corridors of Varying Quality for Amazonian Birds and Mammals	unknown		specific	no	no criteria reported
Lepczyk, et al. (2)	Human Impacts on Regional Avian Diversity and Abundance	weak	yes	vague	no	models within 10% of the weight of top model
Linkie, et al. (3)	Evaluating Biodiversity Conservation around a Large Sumatran Protected Area	weak		vague	no	models within 2 $\Delta$ AIC of top model
Milbau & Stout (2)	Factors Associated with Alien Plants Transitioning from Casual, to Naturalized, to Invasive	unknown		specific	no	no criteria reported
Pope (6)	Assessing Changes in Amphibian Population Dynamics Following Experimental Manipulations of Introduced Fish	weak	yes	specific	yes, model- averaging	Authors used weights comparatively
Sekercioglu, et al. (1)	Climate Change, Elevational Range Shifts, and Bird Extinctions	unknown		vague	yes, apart from model selection	no criteria reported
Sheth, et al. (1)	Effects of Detectability on Estimates of Geographic Range Size in Bignonieae	unknown		non-management	no	lowest AIC value (top model only)
Southwell, et al. (4)	The Sensitivity of Population Viability Analysis to Uncertainty about Habitat Requirements: Implications for the Management of the Endangered Southern Brown Bandicoot	weak		vague	yes, apart from model selection	models within 2 $\Delta$ AIC of top model



Table 2. continued.

Author (Issue #)	Title	Inference Strength	Model Averaged? <sup>a</sup>	Management Recommendation	Acknowledged Uncertainty? <sup>b</sup>	Criteria for Defining Confidence Set <sup>c</sup>
Stephens, et al. (5)	Predicting Risk of Habitat Conversion in Native Temperate Grasslands	unknown		vague	no	lowest AIC value (top model only)
Wiley, et al. (2)	Effectiveness of Voluntary Conservation Agreements: Case Study of Endangered Whales and Commercial Whale Watching	Strong		vague	NA, no	models within 10 $\Delta$ AIC of top model

<sup>a</sup> Did the authors model average?

<sup>b</sup> Did the authors use the term 'uncertainty' in relation to their model selection?

<sup>c</sup> Criteria authors followed for defining their confidence set of models